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WT-1012
(Supersedes ITR-1062)

Operation WIGWAM

May 1955

Project 2.4

DETERMINATION OF RADIOLOGICAL HAZARD TO PERSONNEL

Issuance Date: May 8, 1957

COMMANDER TASK GROUP 7.3

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(Supersedes ITR-1062)

Report to the Scientific Director

DETERMINATION OF RADIOLOGICAL HAZARD TO PERSONNEL

By

M. B. Hawkins, J. D. Sartor, J. E. Howell, M. M. Bigger,
W. S. Kehrer, F. K. Kawahara, F. S. Vine, Hong Lee,
R. H. Black, R. J. Crew, W. B. Lane, and R. R. Soule
U. S. Naval Radiological Defense Laboratory

and

R. Graveson
New York Operations Office, Atomic Energy Commission

QUALIFIED [illegible] THIS REPORT FROM DDC.

Approved by: M. B. HAWKINS
Project Officer
Project 2.4

Approved by: A. B. FOCKE
Scientific Director
Operation Wigwam

Approved by: E. P. COOPER
Director, Program II

U. S. Naval Radiological Defense Laboratory
San Francisco 24, Calif.
July 1956

ABSTRACT

Detailed information about the radiological hazard to personnel on board ships traversing a zone of water contaminated by a subsurface nuclear detonation is developed through consideration of the size, shape, location, and radiation characteristics of the contaminated areas as a function of time. The gamma-radiation intensity at definite shipboard stations during and after traverses through the area, the performance of the washdown system, and the effectiveness of various contamination countermeasures are discussed.

The principal contaminated zone of water was about 5 sq miles at H+19 min; the average "transit" intensities were 25 to 30 r/hr at 3 ft above the surface. Radioactive material decayed during D-day at a rate represented by the exponent −1.5; the over-all decay-dilution exponent was −1.8.

Traversing the contaminated area with the washdown system on did not increase the radiation levels on deck appreciably during the test. Residual radiation levels resulting from the washdown water being contaminated were 4 per cent of the peak intensities encountered on deck.

The radiological situation actually encountered by the test ships cannot be considered tactically serious unless repeatedly encountered. The shipboard situation extrapolated to earlier times is indicated to be potentially serious. However, it is concluded, subject to revision by a more adequate operational analysis, that ships can operate in and around a nuclear detonation as encountered here if interception of the airborne activity and the contaminated water surface is delayed to about H+10 min and if repeated exposures to new detonations are not anticipated.

ACKNOWLEDGMENTS

Project 2.4 could not have achieved any success whatsoever without the wholehearted assistance of many organizations and the personnel therefrom. The unqualified interest, initiative, industry, and cooperation exhibited by all personnel were exceptional. Hazardous work and operations were undertaken without complaint. Three men, J. J. Kearns of the Bureau of Ships and A. E. Brewington (MMC) and L. A. Davis (BT1) of YAG-39, are to be commended highly for their initiative and industry in restoring an engineering casualty on YAG-39. Their efforts, carried out under extremely hazardous respiratory conditions and to almost complete physical exhaustion, allowed YAG-39 to be made available for her mission at the earliest possible time.

The Project Officer wishes to indicate his appreciation for the cooperation and assistance given by the following organizations: New York Operations Office of the Atomic Energy Commission; Bureau of Ships (Codes 538, 254B, and 832); VC-35, Naval Air Station, North Island, San Diego; Tactical Squadron No. 1, Naval Air Station, North Island, San Diego; USS Granville Hall (YAG-40); USS George S. Eastman (YAG-39); USS Molala (ATF-106); USS Mount McKinley (especially Combat Information Center); USS Wright (CVL-49); San Francisco Naval Shipyard; Naval Air Station, Alameda; Mare Island Naval Shipyard; Naval Air Station, North Island, San Diego; Naval Repair Facility, San Diego; Navy Electronics Laboratory, San Diego; HRS-362 (Helicopter Squadron); Bureau of Aeronautics and Naval Air Development Center, Johnsville, Pa.; Texas Instrument Company, Dallas; Edgerton, Germeshausen and Grier, Inc., Boston.

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CHAPTER 1

INTRODUCTION

By M. B. Hawkins, J. D. Sartor, and J. E. Howell

1.1 OBJECTIVES

The experimental objective of Project 2.4 was to obtain information pertinent to the determination of the radiological hazard to personnel on board ships traversing a zone of water contaminated by a subsurface atomic weapon burst. The objective was attained by means of the following measurements:

1. The size, shape, location, and radiation characteristics of the radioactively contaminated area as a function of time.
2. The gamma-radiation intensity at specific stations throughout a ship during and subsequent to traverses through the area.
3. The extent of residual contamination on the hull and exposed surfaces of the ships, the performance of the washdown system, and the effectiveness of various contamination countermeasures.

The operational objectives of Project 2.4 were:

1. To provide Program II Directors, the Task Group Commander, Project 0.17, and other personnel with pertinent information at early times relative to the surface phenomena and the radiological situation.
2. To provide surface and shallow-depth water samples for other projects.
3. To provide facilities, logistic support, and coordination to other projects and programs utilizing the Project 2.4 ships, aircraft, and/or the Program II Plot.
4. To provide assistance, information, and manpower to other projects and programs when feasible.

1.2 BACKGROUND

The radiological hazards to personnel on board ships exposed to a contaminating nuclear weapon detonation has been recognized since the underwater shot at Operation Crossroads. Measurements of gamma-radiation dosage and intensity were made at that event as well as at Operation Castle. However, in these events most of the contaminant was delivered to the ships by, and/or from, the air.

At Wigwam it was anticipated that the contaminating environment would be primarily the surface water and would provide a radiological situation grossly different from any previously encountered. It was recognized that a description of the over-all radiological situation was needed, as was an indication of the radiological hazard to personnel aboard ships near a deep underwater detonation.

1.3 ORGANIZATION AND OPERATIONS PLAN

The project employed two Liberty ships that had been converted for Operation Castle. For that operation these test ships (YAG-39 and YAG-40) were equipped so that they could be operated by radio remote control with no one aboard. They were heavily instrumented for detecting and continuously recording the gamma-radiation intensities at various locations. Each had a flight deck for helicopter landings, and one had a washdown system. The ships were used at Operation Castle for countermeasure evaluation and hazard-determination studies.

The basic operations plan at Wigwam required the ships to steam through the contaminated area as soon as possible after the detonation. Two ships were required to indicate the difference between the situation on a ship with washdown being used and on one with it secured. Two ships were necessary also so that all portions of the project could be accommodated. Estimates of the extent of contamination of the surface water after a deep underwater detonation varied widely, but hazardous radiation-intensity levels were predicted in some cases. Consequently it was unwise to attempt to operate the ships without added protection for the crews. Radio remote control of the ships proved only partly satisfactory at Operation Castle. It was not considered for Operation Wigwam because of (1) the anticipated extreme concentration of ships and boats and (2) the high possibility of spurious interference in the remote-control signals. Therefore a shielded Secondary Control Room was built in each ship to provide adequate protection for any radiological situation except that which required abandoning the room or ship.[1]

Placing operating personnel aboard reemphasized the problem of shock damage. It was important that the ships be at a "safe" shock distance, yet close enough to obtain "early" information. Five miles was estimated to be safe, and this estimation established the entry time as H+35 min. This was too late if the objective of the project was to encompass the tactical situation. Considerable question also existed as to whether the ships would have time to adequately describe and dimension the entire contaminated area since they were slow and had other assignments. The desirability of using aircraft to make a radiological survey of the area became apparent. Simultaneously, the requirement for similar radiological surveys, as well as thermometric survey, for oceanographic and deep-water-detonation phenomenology studies was generated. The aircraft became popular immediately as observation posts and as sampler and radiation-detector dropping platforms.

It had been obvious that the various data had to be correlated with both position and time. Consequently, radar tracking of both test ships as well as of the aircraft was required. In conjunction with other organizations it was established that a fixed buoy would serve as a geographic reference point.

The problem of keeping track of the contaminated area over a several-day period was recognized. It was assumed that the area in a short time would be traceable only by its radiation characteristics; thus, if "lost," it could not be identified by visual means. It was also apparent that the ships (in some cases, the aircraft) should traverse the areas across the maximum dimension. Thus the requirement for a central plotting and data interpretation facility and "Command Post" for Program II was established. The task of planning and operating this control center was assigned to Project 2.4. Since this information would also be useful to the Program II Directors, the Technical Directors, and the Commander, Task Group 7.3 (CTG 7.3), the plotting facility (hereafter labeled Program II Plot) was located on the command ship, AGC-7. The location was logical since certain urgent operational decisions required concurrence of these personnel.

The over-all operational problem of Project 2.4 was complicated not only by the number of organizations involved but also by the inability of anyone to predict to any satisfactory degree the extent and type of surface and subsurface phenomena; consequently, predictions of the distribution and intensity of the radiation field were similarly uncertain. However, limiting assumptions of the magnitude of the phenomena were made, and predictions of the radiological situation were developed. These indicated that the radiological situation could seriously limit the ability of the project to complete its objectives. Hence all plans were developed so that the project had the flexibility and capability of making rapid decisions in order that (1) personnel would not exceed the maximum permissible exposure levels and (2) regardless of the radiological situation encountered, it would be exploited to obtain the optimum amount of data.

1.3.1 Specific Responsibilities

To fulfill its operational requirements and objectives, Project 2.4 was organized into units with Deputy Project Officers as follows:

1. Ship Operations: G. G. Molumphy, CAPT, USN [also Commander, Task Element 7.3.1.7 (CTE 7.3.1.7)].
2. Ship Hazard and Countermeasure Studies: F. S. Vine.
3. Water Sampling and Analysis: R. R. Soule.
4. Aerial Survey and Aircraft Operations: J. E. Howell.
5. Program II Plot: W. B. Heidt, LCDR, USN.

(a) Ship Operations. The principal support unit for Project 2.4 was Task Element 7.3.1.7 (TE 7.3.1.7), consisting of YAG-39, YAG-40, and ATF-106. Projects 2.1 and 2.7 also utilized these ships. The Ship Operations Unit was responsible for planning and coordinating with TE 7.3.1.7 and other authorities:

1. The modifications made to the ships for experimental and operational purposes.
2. The operations of the ships as required by the projects.
3. The use and scheduling of ships' forces to assist with the experimental problems.

(b) Ship Hazard and Countermeasure Studies. The ship hazard and countermeasure studies subproject was responsible for planning, conducting, and reporting the following problems:

1. Decontamination procedures.
2. Countermeasure methods studies.
3. Skin decontamination studies.
4. Basic contamination characteristics studies.
5. Ship radiological monitoring.
6. Dosage and contamination distribution, shielding, and washdown studies.
7. Gamma intensity-time recorder system.

(c) Water Sampling and Analysis. The water sampling and analysis subproject was responsible for coordinating the requirements for samples obtained by YAG-39 and YAG-40 and for planning, conducting, and reporting the collection and automatic analysis of the samples for radioactivity.

(d) Aerial Survey and Aircraft Operations. The aerial survey and aircraft operations were in certain respects a joint responsibility of Projects 2.1 and 2.4. Several areas of authority were retained by the Program Directors. The Project 2.4 portion of the aerial survey was responsible for:

1. Planning, conducting, and reporting the radiological surveys.
2. Coordinating the operational and modification requirements of other projects utilizing the aircraft.
3. Maintaining liaison with, and coordinating the operations as required for aerial survey by, various cooperating units.

The experimental work of the subproject utilized airborne radiation techniques developed by the New York Operations Office (NYOO) of the Atomic Energy Commission. This organization supplied the aerial radiation-detection instrumentation and the telemetering equipment. Their personnel participated in the operation to maintain and operate the telemetering equipment in the Program II Plot.

(e) Program II Plot. The Project 2.4 responsibilities in the Program II Plot were:

1. To collect, correlate, plot, and in some cases interpret and disseminate surface-phenomena information pertinent to the operational phases of Program II.
2. To provide available information to other programs and organizations and in particular to the Task Group Commander.
3. To maintain records of the current status of Program II Project operations and provide operational coordination of these projects.
4. To coordinate the operations of cooperating units.

1.3.2 Ship Operations Plan

Basically, the function of the ships was to be exposed to and collect samples of the surface contaminant. Requirements of both Project 2.4 and Project 2.7 indicated the desirability of intercepting any fall-out. Project 2.1 required that drogue buoys be launched in and near the contaminated area and that deep samplers be streamed from and retrieved by YAG-40.

(a) Operations Plan. In the basic operations plan, YAG-39 and YAG-40 were located 5 miles from Surface Zero (SZ) at shot time, after which they steamed to the contaminated area and traversed it at H+35 to H+50 min. YAG-40 attempted to avoid fall-out. Upon receipt from Program II Plot of information as to the size, intensity, and location of the contaminated area, necessary course changes were made and water sampling procedures were determined. At 1 mile from SZ the drogue buoys for Project 2.1 were launched.

While traversing the contaminated area, water samples were collected, and information about the size, specific activity, and temperature of the water was relayed to Program II Plot.

Three traverses of the contaminated area were made by YAG-40 on D-day, and at the end of each pass the ship moved to an unloading area, where a helicopter landed on the flight deck to pick up water samples for analysis on CVL-49 or for transshipment. The deep samplers were retrieved after the second pass.

Meanwhile YAG-39 attempted to intercept the fall-out. The washdown system was activated immediately after the operating crew descended to the shielded control room. After fall-out had been intercepted, the course was changed to traverse the contaminated area. The washdown system operated during the traverse of the contaminated area and thereafter until it was no longer effective. YAG-39 proceeded to a rendezvous with ATF-106, where monitoring and decontamination experiments began.

On D+1 day YAG-40 again traversed the contaminated area, obtaining water samples and making as many passes as required by Projects 2.2, 2.3, and/or 4.3. Experimental decontamination and monitoring continued on YAG-39 on D+1 and D+2 days.

The test ships and ATF-106 departed for the Zone of the Interior on the evening of D+2 days.

(b) Modification for Operational Purposes. As previously indicated, shielded rooms were provided for an operations crew. Although the recorder room had a 1-ft concrete overhead and had been used at Operation Castle as a control room, it was not deemed satisfactory for the anticipated radiological situation. Therefore special rooms were fabricated in Hold 3 of each test ship (Fig. 1.1). To provide shielding from radiation, these rooms were completely surrounded by 6 to 15 ft of sea water (normally required for ballasting) except for an access trunk in one end of the room.

From a study of the effect of oxygen depletion and carbon dioxide buildup on the 12-man operating crew who would man the secondary control room, it was found that neither discomfort nor anoxia should result under the most pessimistic operating conditions.

So that the ships could be safety controlled, operated, and navigated from the shielded rooms (officially called the Secondary Control Room), the following special equipment was installed:

1. Ship control and navigation equipment:
   a. Radar repeater.
   b. Gyrocompass.

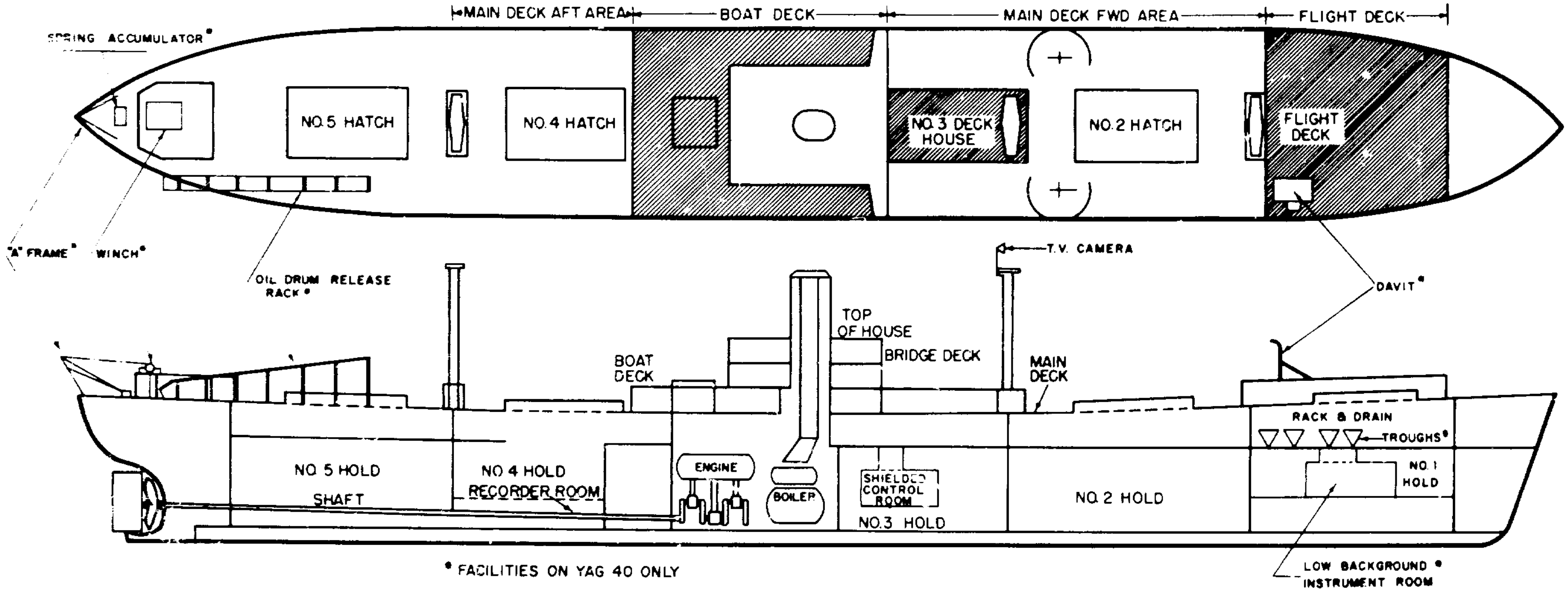


Fig. 1.1—Plans and side view showing special facilities on YAG-39 and YAG-40.

c. Rudder angle indicator.

d. RPM indicator.

e. Closed-circuit TV system. This provided the visual picture "seen" by a TV camera mounted on top of the forward kingpost. Remote-controlled pan and tilt systems allowed the operator to scan the horizon with the camera and look down at the decks of the ships. Azimuth readings were provided on the control unit so that bearings on other ships could be taken.

f. Remote-control system for speed and course. The radio remote-control systems on YAG-39 and YAG-40, which were previously installed for Operation Castle, provided the means of controlling the ships' speed, course, and instrumentation functions from locations distant from the normal operating positions. A unit to control the throttle and rudder was installed in the Secondary Control Room, thus eliminating the need for personnel in the engine room or on the bridge. At Operation Wigwam a remote-control station involving a "radio" link was placed on ATF-106 and was ready at all times to take over control of either or both ships should emergency evacuation of either YAG-39 or YAG-40 be required.

2. Ship's machinery equipment:

a. A closed-circuit TV system independent of that for conning the ship was installed between the engine room and the Secondary Control Room. A TV camera in the engine room was installed in front of the gauge board. By means of a remote-control pan and tilt system, the ship's engineer in the Secondary Control Room could observe gauges indicating steam pressures and boiler water levels.

b. Emergency shutoffs for fuel and washdown pumps were installed.

3. Ship communications equipment:

a. A TED-URR-13 UHF voice radio was installed for ship-to-ship and ship-to-helicopter communications.

b. Remotes from existing and new radio equipment were installed in the Secondary Control Room.

c. FM transceivers for project communications between ships were installed with remotes to the Secondary Control Room.

(c) Modifications for Experimental Purposes. To provide facilities and equipment for the experimental programs, certain modifications of the two test ships were made. A summary of these modifications follows:

1. Water sampling facilities:

Facilities were installed on YAG-40 to collect samples of the surface contaminant while the ship was traversing the area. Collection was with an underwater scoop attached to the keel or from a sled towed alongside the ship. A pump delivered the water to a manifold system on the second deck where samples were taken as required.

To determine the specific activity of the water being collected as a function of time, a low-background room was installed in the lower section of Hold 1. The construction of this room was similar to that of the Secondary Control Room, and the room was shielded by 6 to 10 ft of water. Special counting equipment was installed in the room, and a portion of the water being collected was diverted through the analysis system, which automatically recorded the information desired.

The information obtained by the analysis system was also sent by remote control to the Secondary Control Room, where the project personnel in charge of water sampling could control the automatically operated manifold system to obtain samples when desired.

2. Project 2.1 deep-tow facilities:

To provide facilities for Project 2.1 to obtain water samples at depths down to 2000 ft, a special installation consisting of an A-frame, winch, and accumulator were installed on the stern of YAG-40.

3. Project 2.1 drogue buoy facilities:

A special drum rack was installed on the starboard side of YAG-40, and this allowed 25 drogue buoys to be launched remotely from the Secondary Control Room while the ship traversed the contaminated area.

4. Project 2.7 fall-out collectors:

Fall-out collectors were installed on the forward kingpost of each test ship for Project 2.7. Automatic starting and recording equipment for the collectors was located in the Secondary Control Room.

(d) Communications. Communications between YAG-39, YAG-40, ATF-106, and the Program II Plot on AGC-12 were accomplished primarily by means of the Project 2.4 FM transceiver net (Channel George) operating on a frequency of 153.35 Mc. In case of failure, an alternate Task Force communications net could be used for vital messages. Figure 1.2 illustrates the entire communications system for Project 2.4.

During critical operational periods, all voice transmissions between YAG-39, YAG-40, and the Program II Plot followed a prearranged message schedule. Besides providing efficient use of transmission time, the message schedules essentially eliminated the possibility of security violations.

(e) Operations Base on ATF-106. ATF-106 was utilized as a base of operations for the postevent decontamination and technical monitoring of YAG-39 and YAG-40. Consequently, the decontamination supervisors, monitors, and Rad-Safe personnel, as well as the decontamination personnel, were processed from ATF-106, utilizing M-boat transportation to and from the YAG's.

ATF-106 was also a base of operations for the relief operating crews of YAG-39 and YAG-40. These crews were available to exchange with the operating crews at 12-hr intervals or sooner if found necessary.

(f) YAG Operating Crews. YAG operating crews were members of the ships' crews and project personnel. They were assigned to man the Secondary Control Room while the ships traversed the contaminated area. The basic operating crews for ship control consisted of one officer and seven enlisted personnel who were specialists in the various functions of ship operations. The remainder of the operating crew were project personnel and were responsible for various portions of the project as well as radiological safety precautions.

1.3.3 Aircraft Operations

The functions of the personnel aboard the aerial survey aircraft were imposed by the objectives of Projects 2.4 and 2.1 as well as the requirements of Projects 2.6, 2.7, and 0.17 and the Program II Directors. These were:

1. To observe, describe, and report any visible phenomena.
2. To orient the aircraft and operate equipment so that fixed instrumentation could indicate the temperature and radiation intensity of the contaminated surface.
3. To drop samplers and telemetering radiac detectors.

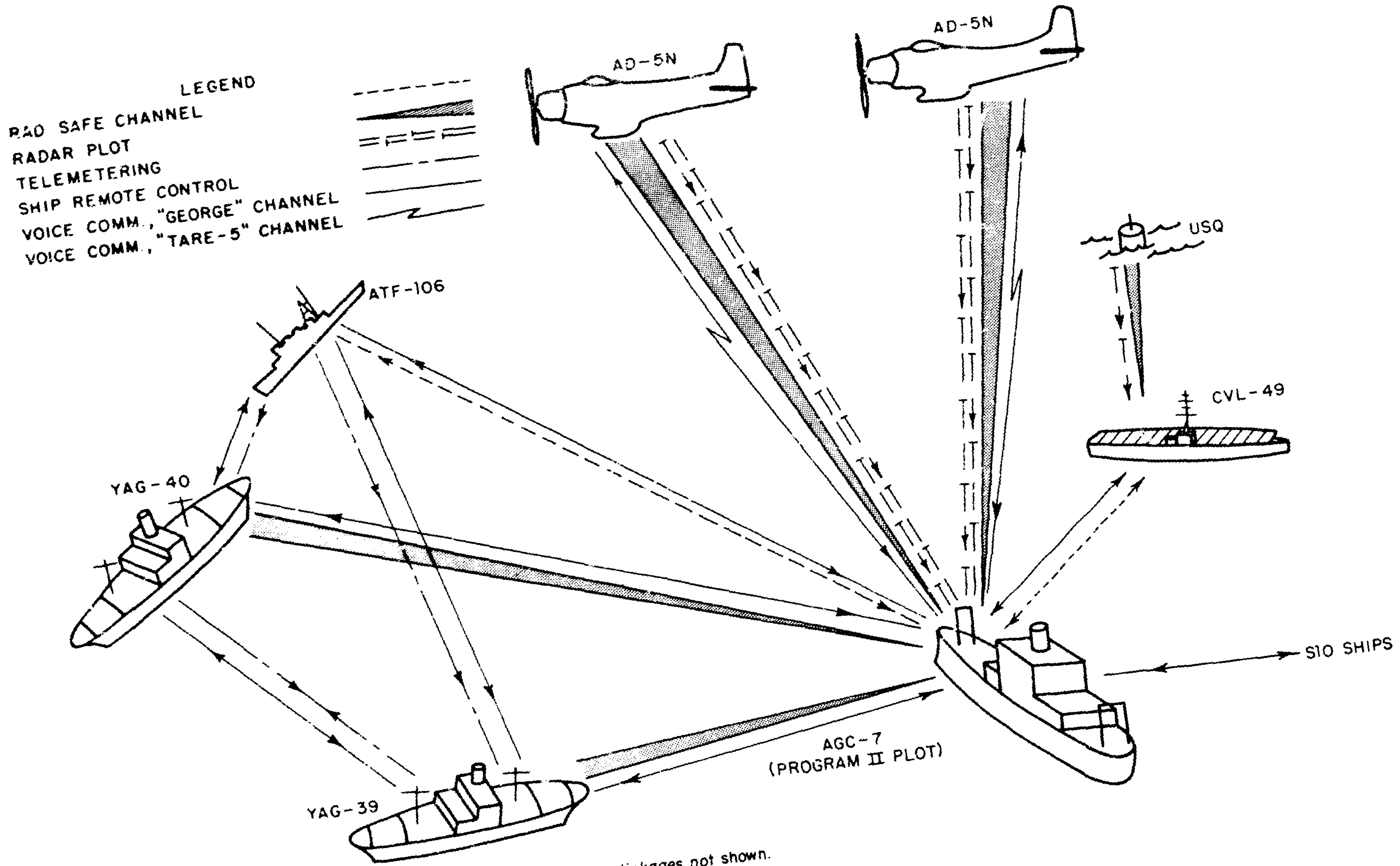
Besides the normal hazards of aircraft operations at sea, radiological hazards were anticipated. Techniques were developed for predicting the diameter of the area and the dosage that would be received on subsequent passes based upon radiation-intensity readings taken in the cockpit at the perimeter of the area. Their use was incorporated into the aerial survey operations plan.

Avoidance of airborne material was required not only from a safety standpoint but also to keep the radiological background of the detection instrumentation in the aircraft low. Radiological safety responsibility was retained by CTG 7.3 until the critical period was completed.

During all flights two aircraft flew in mutual convoy. Since they were instrumented similarly, this plan provided (1) duplicate data, (2) the ability to complete the mission in case of the failure of one aircraft, and (3) maximum operational safety.

Operational control was maintained through the Tactical Air Control Squadron (TACRON) Unit on AGC-7. Establishing the position of the aircraft vs time was a joint TACRON–Combat Information Center (CIC) effort on AGC-7.

(a) Flight Plans. Flight patterns for various phases of the operation were planned. The basic flight plan for the first series of passes across SZ (Fig. 1.3) was planned so that (1) the



NOTE: Standard communication linkages not shown.

Fig. 1.2—Communications system for Project 2.4.

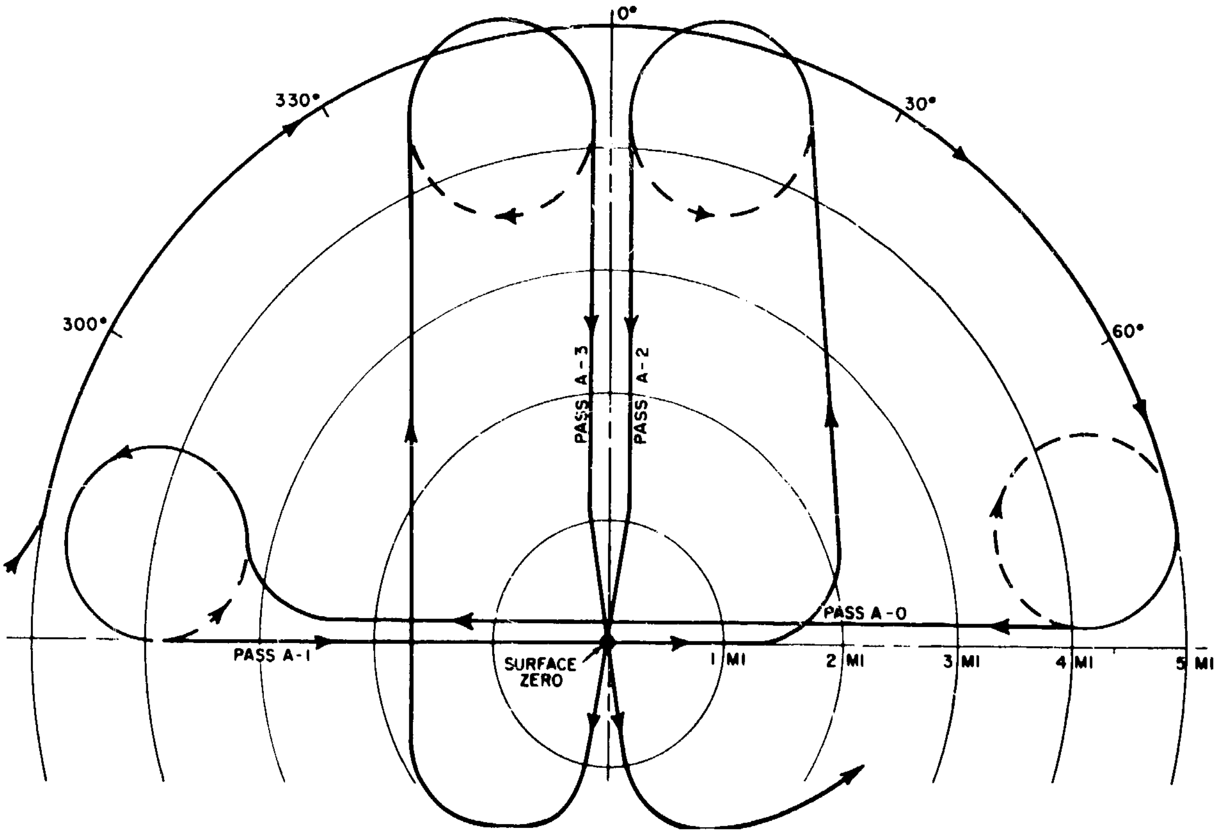


Fig. 1.3—Aerial survey flight plan "Alpha" for Project 2.4.

aircraft would proceed around the upwind half of the 5-mile circle to allow the technical observers to view the surface phenomena resulting from the underwater detonation, (2) entry into the area over SZ would be delayed until it had been estimated that any airborne contaminant had been dispersed, (3) an offset "snooping" (1000 ft upwind of SZ and at a 1500-ft altitude) pass would be made initially for purposes of estimating the radiological hazard, (4) the second and subsequent passes would be at a 500-ft altitude, and (5) all passes in the first series would be confined to the region upwind of SZ as much as feasible to minimize interception of airborne contaminant.

Subsequent series of passes were conducted on a "clover-leaf" type pattern or a series of parallel passes, depending upon the situation. The specific area surveyed on any series of passes was determined in the Program II Plot on the basis of previous information. Directions were given to TACRON, whose function was to "conn" the aircraft to the specified area.

(b) Aircraft and Modification. AD-5N type aircraft were selected for the aerial survey operations because (1) they had adequate space to install necessary detection equipment and sufficient bomb racks for carrying and dropping the water samplers; (2) they could be carrier based, thus allowing all personnel to operate from the same area; and (3) they were the most dependable and most readily available of the types of aircraft considered adequate for use in this operation. Two aircraft were outfitted completely with the required equipment; a third was outfitted with the necessary cables and brackets in a manner that would permit the equipment from one of the other aircraft to be installed if necessary. This spare aircraft was kept ready for use at all times.

The principal modifications* to the aircraft were those necessary for the installation of experimental instruments. The control and recording equipment for the radiation- and temperature-detection systems, the communications transceivers, and a type USQ radiac receptor were located in the after cockpit, as was an extra seat for an equipment operator. The detector for radiation-survey gear was located in the tail section, and the detector for the temperature-survey gear was located on the starboard wing root about 6 ft from the fuselage. Remote indicating instruments for the two detection systems were installed in front of the observer in the forward cockpit.

(c) Communications. Commercial FM transceivers of five different frequencies were used for voice communications and for telemetering data from the aircraft. Standard existing UHF radio equipment was utilized by the pilots of the survey aircraft for voice communications with the TACRON group on AGC-7 and the flight control personnel on CVL-49.

Security in communications was achieved in that (1) the FM transceivers and the UHF communications were limited in range and (2) voice codes were used when classified information was transmitted. Message schedules were prepared and employed during the operational phases to adequately program the time on the channels and prevent interference between the various groups using these channels.

Owing to the limited range of the communications equipment and the interference caused by other electronic and electrical equipment, the communications were far from satisfactory. Although reception faded completely during some of the most critical times, operations were not interrupted nor was safety compromised. The pretest planning and personnel indoctrination proved adequate to meet such emergencies.

1.3.4 Program II Plot and Position Plotting

As previously indicated, an extremely flexible operations plan was required for the ships and aircraft of Project 2.4. The adoption of alternate plans had to be carefully coordinated to maintain an orderly situation and had to be based on evaluation of all available data pertinent to such decisions. The Program II Plot was established to provide for these functions. Project 2.4 was assigned responsibility for planning and operating the Program II Plot in conjunction

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*These modifications were done by the Overhaul and Repair Department at the Naval Air Station, Alameda, Calif.

Table 1.1 — SOURCES OF INFORMATION TRANSMITTED TO PROGRAM II PLOT

Source	Type of data	Transmission mode, route, and circuit
1. Project observers in aircraft	Oral description of surface phenomena; Rad-Safe situation in plane; location of flotsam and location of samplers	Direct voice linkage: two aircraft to Program II Plot; Channel Tare 5, one frequency; information to be logged and tape recorded
2. NYOO-AEC radiac survey equipment	Radiation intensity of area beneath aircraft vs time	Telemetered from two aircraft direct to Program II Plot; Channel Tare, two frequencies; data to be recorded automatically (Esterline-Angus recorders)
3. SIO-WHOI bolometer	Surface temperatures beneath aircraft	Telemetered from two aircraft direct to Program II Plot; data to be recorded automatically
4. TACRON organization on AGC-7	Locations of aircraft relative to fixed point, e.g., SZ (note: CIC to supply TACRON with data for relating AGC-7 position with fixed point)	Data logged and passed to Program II Plot; data phoned to plot board
5. YAG-39 project personnel	Miscellaneous operational information; fall-out information; YAG Rad-Safe data	Direct voice linkage: YAG to Program II Plot; Channel George; information data to be logged and tape recorded
6. YAG-40 project personnel	Miscellaneous operational information; contaminated water radiation and temperature data; sample data; Rad-Safe data; etc.	Same as item 5
7. ATF-106 project personnel	Miscellaneous operational information; YAG-39 monitoring and decontamination information	Same as item 5
8. CIC, AGC-7	Positions of YAG's 39 and 40, Horizon, and T-boat	Data logged and passed to Program II Plot; data phoned to plot board
9. USQ system on CVL-49	Radiation intensity of water; buoy location	Radiation intensity telemetered from buoys to CVL-49; voice transmission from CVL to Program II Plot (data logged)
10. Two aircraft pilots	Alternate to item 1 in event of equipment failure in Channel Tare 5; use to be limited to most important items only	Remote circuit is required in Program II Plot
11. YAG's 39 and 40 and AFT-106: ships' forces	Alternates to items 5. 6, and 7 in event of equipment failure in Channel George; use to be limited to most important items only	Remote circuit is required in Program II Plot
12. Aircraft position plot on destroyers	Alternate to item 4 in the event of equipment failure	Remote circuit is required
13. SIO ships	Radiation and temperature data at various depths	Direct voice linkage from Horizon to Program II Plot

Fig. 1.4—General view of operations area at Program II Plot.

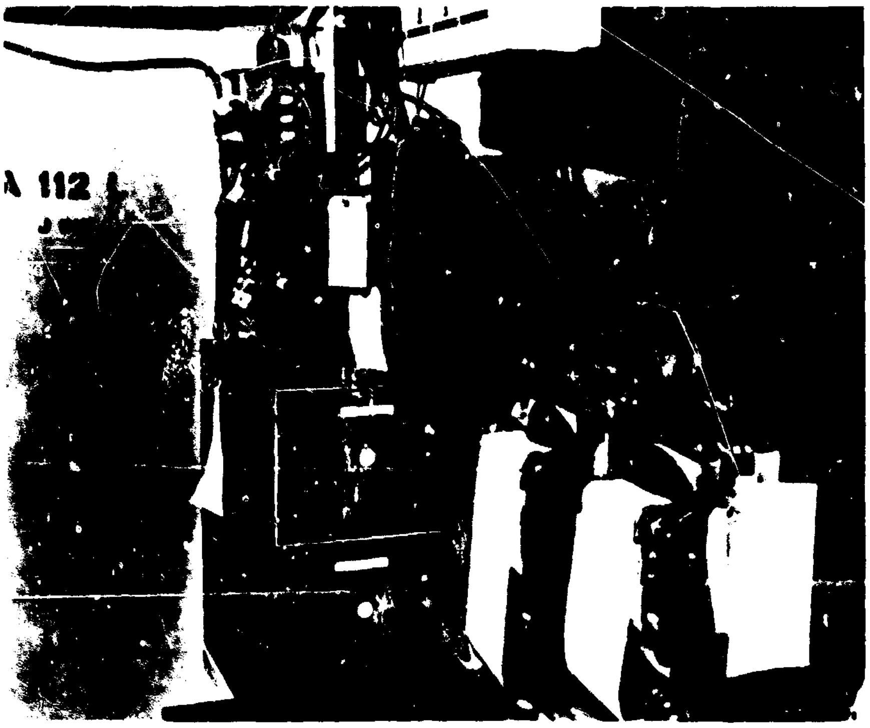

Fig. 1.5—Aircraft and ship position plotting.

Fig. 1.6 — Telepulse central stations in Program II Plot.

with the CIC organization of AGC-7 and the TACRON organization of Task Group 7.3 (TG 7.3). The Program II Plot was located in the Joint Operations Command (JOC) of AGC-7.

The function of Program II Plot was to collect information from various sources, correlate and interpret it, and disseminate it. In addition, Project 2.4 utilized the facility to direct and control the operations of the ships and aircraft of the Project.

(a) Operations. Table 1.1 indicates the type of information received by the Program II Plot, the source of the information, and by what means it was received. In all, 13 radio channels and six sound-powered phone circuits were required in the Plot. Figures 1.4 to 1.6 show the general arrangement and facilities required. Working space was provided for the Program II Directors, a Scripps Institution of Oceanography (SIO) representative, and the Project Officer of Project 0.17.

(b) Position Plotting. Program II Plot was responsible for coordinating the position plots of the Project 2.4 ships and aircraft. Radar operators in the CIC of AGC-7 were to record the range and bearing (and time of reading) of the ships and aircraft from AGC-7. AGC-7 would hold position on a buoy which would be at a known location with respect to SZ. Timing, i.e., the correlation of events with location, would be accomplished by careful recording of time with synchronized clocks.

REFERENCE

1. J. D. Teresi, M. B. Hawkins, and R. R. Soule, Estimation of Radiological Situation During Operation of YAG's 39 and 40 at Operation Wigwam, U. S. Naval Radiological Defense Laboratory Secret (RD) Document 0010929, 12 August 1954.

CHAPTER 2

OPERATIONS

By M. B. Hawkins, J. D. Sartor, M. M. Bigger, and J. E. Howell

2.1 SHIP OPERATIONS—GENERAL

YAG-39 and YAG-40 departed from San Francisco Naval Shipyard on 2 May 1955 for Point Yoke, where they were to rendezvous with TG 7.3. At departure time all experimental and operational equipment was in readiness for the operation. ATF-106 joined the ships en route and remained as escort throughout the operation.

After arrival in the operating area, several practice runs of the basic operations plan were made by YAG-39 and YAG-40. Coordination of the ships' movements by the Program II Plot on AGC-7 were rehearsed. Plotting procedures and message schedules were established. One run was conducted in conjunction with the aerial survey project, coordinating the YAG movements with dummy information received from the survey planes.

At H-hour on D-day the operating crews and project personnel were stationed on the flight deck. Approximately 4 sec after the surface phenomena were observed, the first shock wave arrived at the ships. The ships appeared to flex as the shock wave traveled from bow to stern. Almost immediately a second shock of higher intensity than the first wave hit the ships. The shock vibrations persisted for an estimated 25 sec. The arrival of the shock wave caused minor damage to both ships,* and this delayed execution of the basic operations plan.

Communications between the Program II Plot and the test ships became intermittent and unreliable after H-hour. The antennas for Channel George were so located on AGC-7 that signals from other operating channels periodically interfered with transmission. The backup channel (Channel 9A), being the tactical net, had considerable other traffic and could not be used efficiently to supplement Channel George. Communication difficulties, while bothersome, did not delay the operation much.

Because of the shielding afforded operating personnel in the Secondary Control Room and because of the Rad-Safe procedures employed, the dosage received by the personnel on YAG-39 and YAG-40 during the entire operation was very low; the highest total dosage received was 200 mr.

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*J. D. Sartor, Summary of Operational Casualties Incurred on Board the YAG-39 and YAG-40 During Operation Wigwam, Confidential memorandum (unpublished) JDS:jmb of 19 August 1955.

2.2 YAG-39 OPERATIONS

The plot of YAG-39 maneuvers during the operation is shown in Fig. 2.1. The shock-wave damage started a series of events that caused the ship to become dead in the water at H+65 min. Airborne activity was intercepted by the ship; at H+13 min the gamma detector station on the forward kingpost indicated an intensity of at least 400 r/hr. At H+37 min the readings on the decks were 45 mr/hr.

At H+34 min it became obvious that YAG-39 could not continue on its basic operations plan because of damage, and the ship's course was changed to avoid the contaminated area.

Through the combined efforts of the ship's engineering personnel and project personnel on board, the engine room was made ready for operations at approximately H+5 hr. At this time, only one boiler was in operation since the other boiler had suffered a tube casualty.

Owing to the reduced speed of the ship and the lateness of the day, the operations plan was discontinued. The radiological history of YAG-39 during the operation is shown in Fig. 4.1.

On the morning of D+1 day, an attempt was made to fulfill as much of the mission of YAG-39 as possible. YAG-40 had intercepted the contaminated area, and YAG-39 proceeded to YAG-40's position and activated the washdown system when an increase of radiation levels was indicated. As indicated in Fig. 4.1, only low radiation intensities were encountered by the ship on the pass through the contaminated area; no further traverses were made.

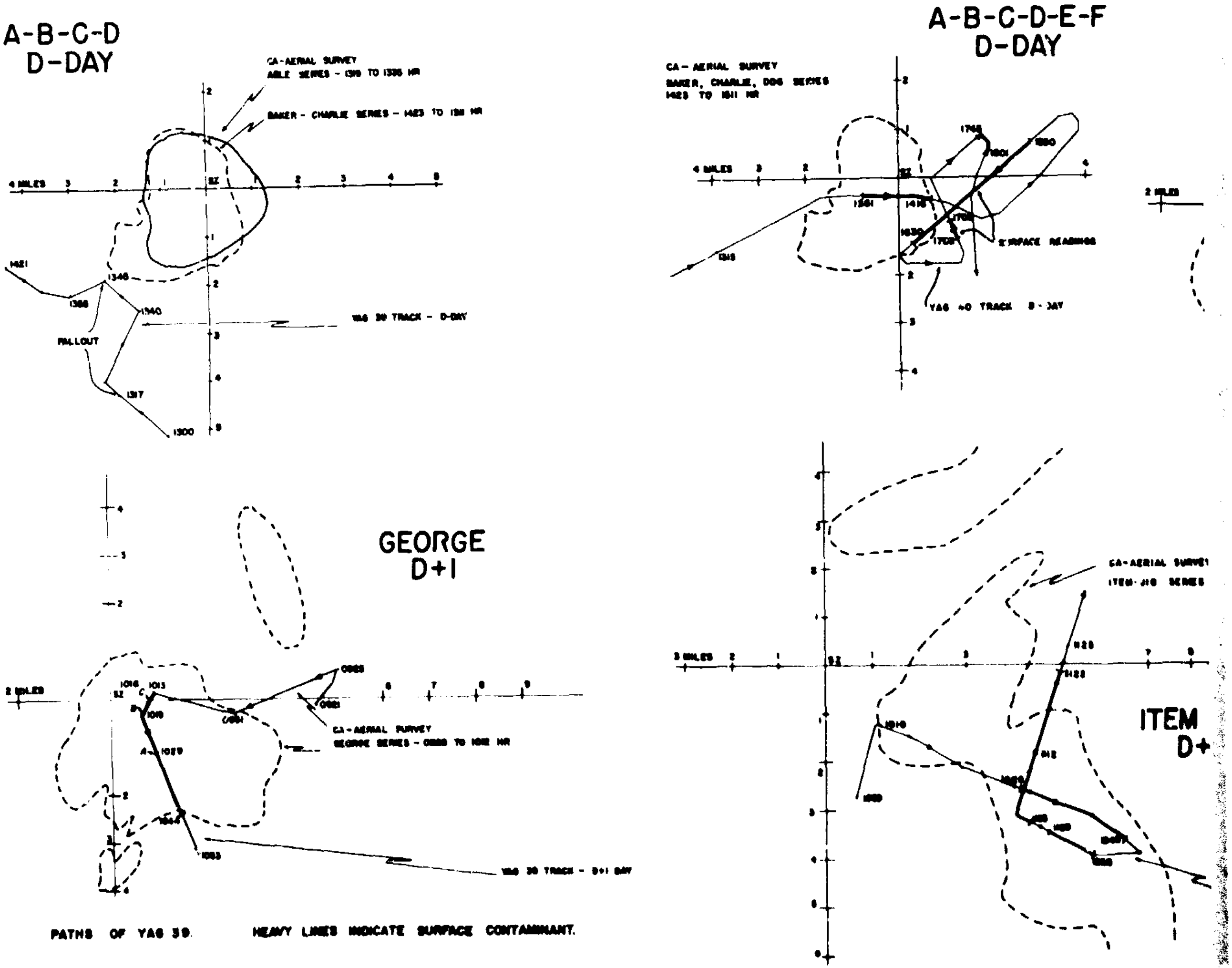
YAG-39 was released by Task Unit 7.3.1.7 (TU 7.3.1.7) and CTG 7.3 on the afternoon of D+1 day and directed to return to the ZI under the escort of ATF-106. Because only one boiler was in operation, the trip was made at reduced speed. YAG-39 arrived at San Francisco Naval Shipyard on 19 May 1955.

After arrival, a complete radiological survey was accomplished on YAG-39. A detailed report of that survey is given in Table 2.1. Operational clearance was granted the ship after a few "hot" spots were decontaminated.

Table 2.1 — RESULTS OF RADIOLOGICAL SURVEY ON YAG-39 AFTER ARRIVAL AT SAN FRANCISCO NAVAL SHIPYARD

Item	Radiation level,* counts/min	
	Open window	Closed window
Washdown sprinkler heads		
Portside of hatch 4	50,000	3,000
Top of deckhouse (4 heads)	20,000–50,000	500–6,000
Jack-staff base	50,000	10,000
Lifeboat supports (boat deck)	25,000–50,000	2,000–4,000
Lifeboat davits (boat deck)	15,000–50,000	1,500–4,000
Scuppers: boat deck, port, forward	20,000–50,000	500–2,000
Wrapped wire line, starboard, aft lifeboat rigging	50,000	2,000
Washdown diesel No. 2: intake manifold	20,000	1,000
Removable (wipe count taken on manifold that had been removed)	4,000	

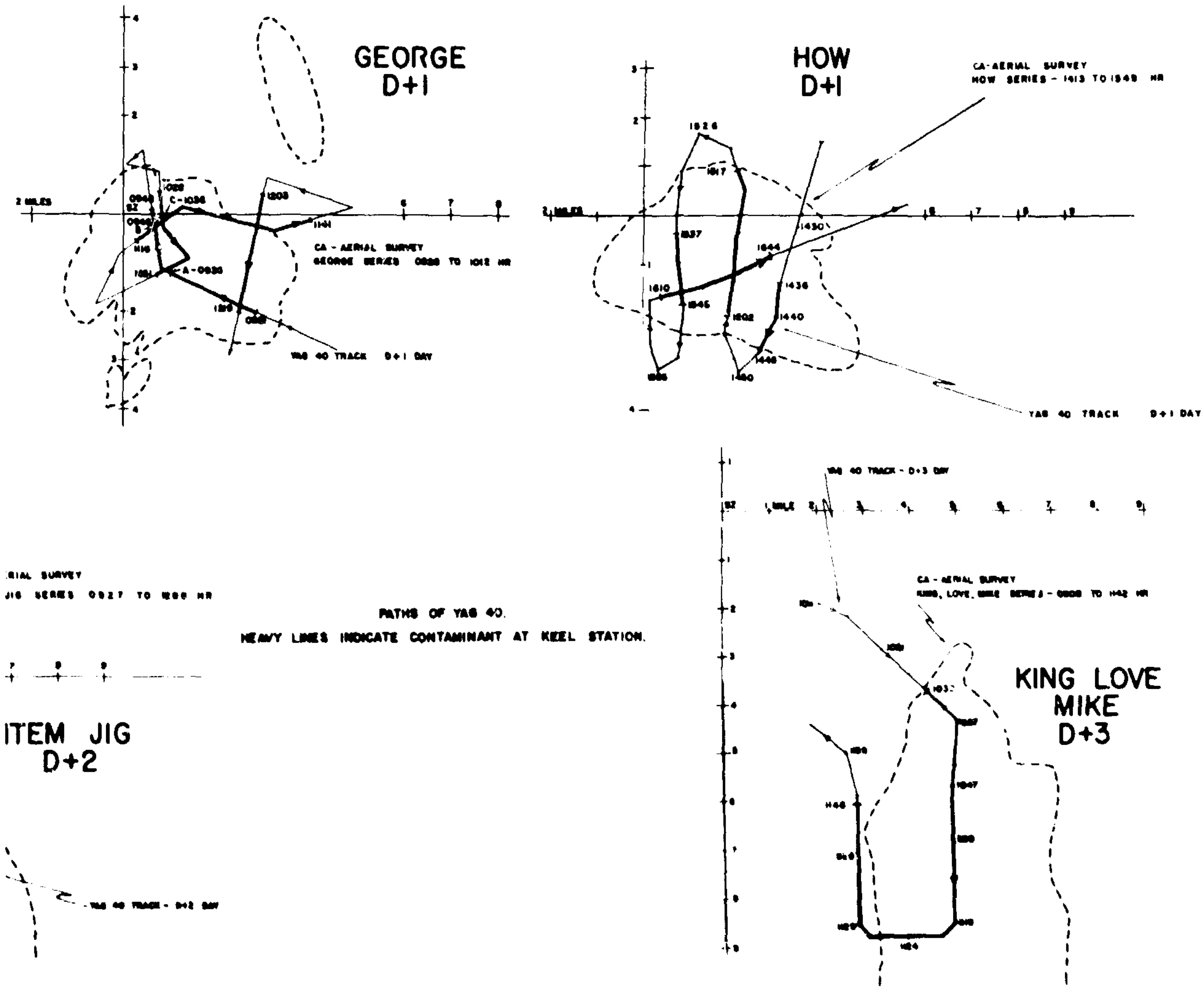
*The survey was performed with two Berkeley survey meters, model 2750-1. The instrument indication was in counts per minute and necessarily required a calibration in order to correlate readings with final-clearance level as prescribed in NAVMED P-1325. Final-clearance gamma-radiation level is defined as 1.8 mr/hr and corresponds to a meter reading of 4500 counts/min, closed window (CW). Final-clearance beta-radiation fixed level corresponds to a meter reading of 22,500 counts/min, open window (OW). Removable radioactive contamination was measured using nonstandard techniques; readings of 2000 counts/min (OW) are above allowable final limit, considering techniques utilized.



PATHS OF YAG 39. HEAVY LINES INDICATE SURFACE CONTAMINANT.

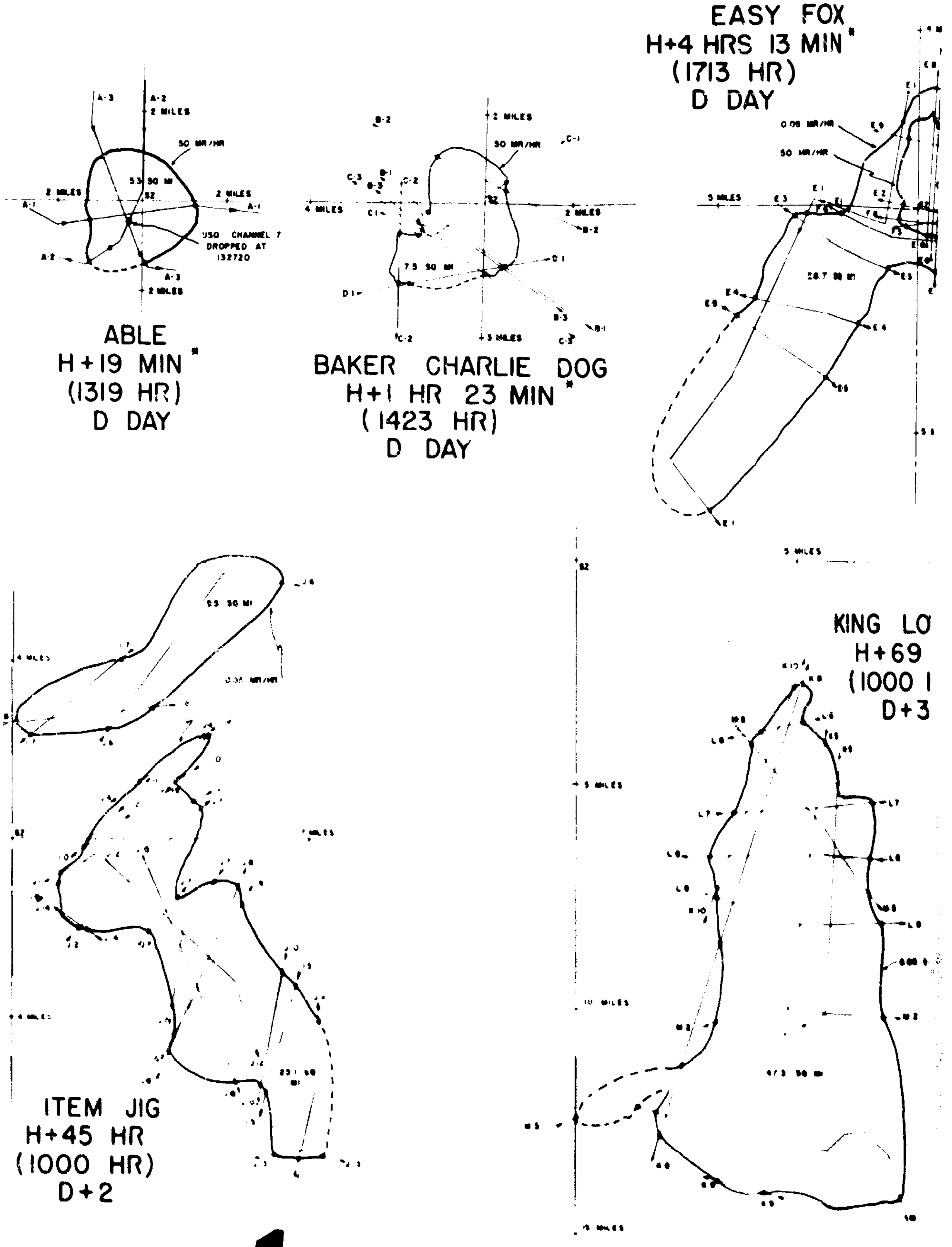
Fig. 2.1—Paths of YAG-39 and YAG

1



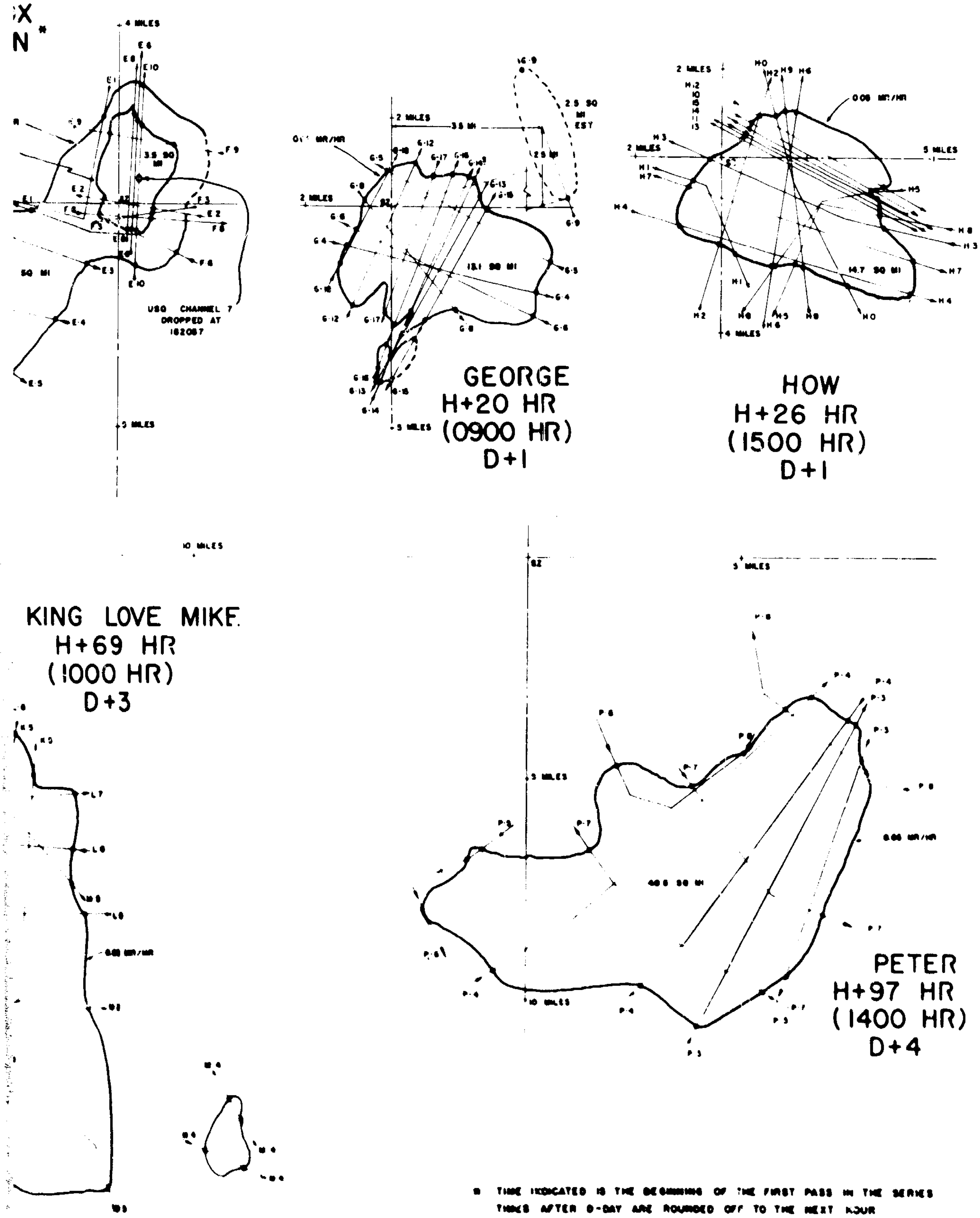
d YAG-40 at Operation Wigwam.

2



1

Fig. 3.8 — Outlines of contaminate



* TIME INDICATED IS THE BEGINNING OF THE FIRST PASS IN THE SERIES
TIMES AFTER D-DAY ARE ROUNDED OFF TO THE NEXT HOUR

of contaminated areas through D+4 days.

2.3 YAG-40 OPERATIONS

After a short delay caused by minor shock damage, YAG-40 proceeded toward SZ on the basic operations plan. The radiation field from the contaminated area was intercepted at H+41 min by the gamma detector station on the forward kingpost. The contaminated water was intercepted by the ship at H+51 min, as indicated by the gamma detector station on the keel.

After completing Pass 1, YAG-40 moved to a rendezvous area where the water samples were transferred to a helicopter for transport to CVL-49. Upon completion of the transfer, Passes 2 and 3 were made through the contaminated area.

A plot of YAG-40 operations is included in Fig. 2.1. The radiation intensities during the passes are given in Fig. 4.4. Water samples were taken on all three D-day passes, and certain samples from each pass were delivered to CVL-49 after Passes 1 and 3.

The Project 2.1 deep tow was retrieved after Pass 3 at H+5 hr. One sampler was missing. None of the samplers retrieved had been tripped by the automatic radiation trigger.

The Project 2.1 drogue buoys were released on Passes 1 and 2. Difficulties were encountered in releasing the buoys remotely during Pass 1. Upon examination after the ship was out of the contaminated area, it was found that the buoys had been disarranged by the shock wave and had jammed the rack. The remainder of the buoys were released manually during Pass 2.

YAG-40 traversed the contaminated area, obtaining water samples for Project 2.6 on D+1 day and conducting a radiological survey on D+2 and D+3 days. The traverses on D+2 and D+3 days were made in conjunction with the aerial survey planes, which dropped smoke pots in the area when indications of radiation were detected by the aerial survey equipment.

YAG-40 was released by TU 7.3.1.7 and CTG 7.3 on D+4 days; it returned to San Francisco Naval Shipyard, arriving 20 May 1955. Upon arrival a radiological survey was accomplished, and the results are given in Table 2.2. Operational clearance was granted to YAG-40 with certain limitations prescribed during shipyard work.

2.4 AIRCRAFT OPERATIONS

After completion of their modifications, the aircraft were flown to the Nevada Proving Grounds, where NYOO-AEC personnel and equipment were participating in Operation Teapot. Flights were made over contaminated areas to check the compatibility of the radiation-detection and telemetering equipment and to train project personnel to operate it. Flights to check equipment were made at San Diego before the Task Group departed.

At sea, one flight was made before D-day to check procedures, equipment, operations plan, and communications.

From D-day to D+4 days, seven survey flights were made (see Table 2.3). The H-hour flight (on Flight 1) water samplers and radiac telemetering devices were dropped, and surveys were made with radiation- and temperature-detection equipment. When no detectable temperature difference was found on Flight 1, the subsequent flights determined only the radiation intensity of the contaminated area. Additional radiac telemetering units were dropped on Flights 2 and 3. All other flights were launched solely for radiological surveys.

On D+2 days it became apparent that the radiation levels were too low for Project 2.4 objectives.

2.4.1 Operations During Able Series

After the survey aircraft were launched at H−1 hr, communications checks were made between Program II Plot and the aircraft. A radiation source and a known temperature source were placed on the deck of the Horizon. The survey aircraft made several passes over this ship to check their radiation- and temperature-detection equipment and then proceeded to their preshot position, where final operational instructions were given by Program II Plot.

At H-hour both survey aircraft were proceeding around the upwind edge of the 5-mile circle. The aircraft were ordered by Program II Plot to orbit once before initiating the first

Table 2.2—RESULTS OF RADIOLOGICAL SURVEY ON YAG-40 AFTER ARRIVAL AT SAN FRANCISCO NAVAL SHIPYARD

Item	Radiation level,* counts/min	
	Open window	Closed window
Fire sprinkler		
Starboard, approximately frame 82	50,000	3,500
Removable from inside	2,500	600
Contamination inside valve	15,000	2,500
Hangar-deck tie-down channels	50,000	2,000
Roller chocks		
Port, approximately frame 5	50,000	20,000
Removable	4,000	
Starboard, approximately frame 5	50,000	20,000
Removable	None	
Hatch wedges (on hatch 2)	50,000	3,000
3-in.-gun mounts		
Port	50,000	25,000
Starboard	20,000–40,000	1,000–40,000
Life raft cover (temporarily located starboard, approximately frame 55)	40,000	4,000
Air scoop (port, frame 115, main deck)	50,000	3,000
Diesel intake stack (frame 136)	50,000	7,000
Void vents (starboard, frame 90), patches	50,000	5,000
Lifeboat davit handles (forward, starboard)	50,000	5,000
Hand railing and posts (boat deck, starboard)	50,000	5,000
Deck at after corners of pilot house	50,000	25,000
Davit (aft, starboard corner of top of deckhouse)	40,000	7,000
Stay brace for galley stack, patches	50,000	20,000
Signal halyard hooks	30,000	1,000
Cleat (port, top of deckhouse)	50,000	20,000
Door to deckhouse (starboard, frame 70)	50,000	2,000

* The survey was performed with two Berkeley survey meters, model 2750-1. The instrument indication was in counts per minute and necessarily required a calibration in order to correlate readings with final-clearance level as prescribed in NAVMED P-1325. Final-clearance gamma-radiation level is defined as 1.8 mr/hr and corresponds to a meter reading of 4500 counts/min, closed window (CW). Final-clearance beta-radiation fixed level corresponds to a meter reading of 22,500 counts/min, open window (OW). Removable radioactive contamination was measured using nonstandard techniques; readings of 2000 counts/min (OW) are above allowable final limit, considering techniques utilized.

Table 2.3 — AIRCRAFT OPERATIONS

Flight	Date	Aerial survey series completed	Purpose*
1	D-day	Able, Baker, Charlie, Dog	Radiation survey (2.4); drop radiac telemetering buoys (2.4); thermometric survey (2.1); drop water samplers (2.1)
2	D-day	Easy, Fox	Radiation survey (2.4); drop radiac telemetering buoys (2.4)
3	D+1	George	Radiation survey (2.4); drop radiac telemetering buoys (2.4)
4	D+1	How	Radiation survey (2.4)
5	D+2	Item, Jig	Same as Flight 4 above
6	D+3	King, Love, Mike	Long-term radiation survey (2.1)
7	D+4	Peter, Queen	Same as Flight 6 above
P-1	D-3		Practice only

* Number in parentheses indicates the cognizant Project.

Able pass (Able-0) (Fig. 1.3). This order delayed the start of the Able-0 pass until about H+11 min. The radiation-intensity information in the cockpit when the aircraft was over the towing array (1200 mr/hr) and 10 sec thereafter (800 mr/hr) was transmitted immediately to Program II Plot. At the end of the pass the total dose received (18 mr) was also transmitted. This information was sufficient to provide a basis for radiological clearance for the next pass.

The Able-1 pass was the first drop-pass and was made from west to east across SZ. Samplers and radiac telemetering units were dropped as indicated in Table 2.4. After each pass the total radiation dosage received in the cockpits of the survey aircraft were reported to the aerial survey supervisor. The total dose for the Able series was approximately 300 mr. Upon completion of this series the survey aircraft were ordered to orbit while the data were analyzed and the radiological situation was reestimated.

Table 2.4 — DROP SEQUENCE FROM AERIAL SURVEY AIRCRAFT

Aircraft	Pass	Equipment dropped	Drop interval, sec
NR-92 (Survey 2)	Able-1	11 samplers	1
NR-82 (Survey 1)	Able-2	5 USQ-1 telemetering units	5
NR-82 (Survey 1)	Able-3	11 samplers	1
NR-82 (Survey 1)	Dog-1	2 USQ-1 telemetering units	15
NR-92 (Survey 1)	Easy-8	1 USQ-1 telemetering unit	
NR-92 (Survey 1)	Easy-10	4 USQ-1 telemetering units	15
NR-82 (Survey 2)	George-12	2 USQ-1 telemetering units	15

The flight plan followed during the Able series was approximately as originally planned. Some difficulty was encountered owing to the inaccuracy in the TACRON control. However, the presence of debris and dye around SZ aided the aircraft crews in locating the contaminated area.

2.4.2 Operations After Able Series

A clover-leaf flight plan was used during the Baker, Charlie, and Dog series. Each pass in this flight plan was made across what was assumed to be the center of the contaminated

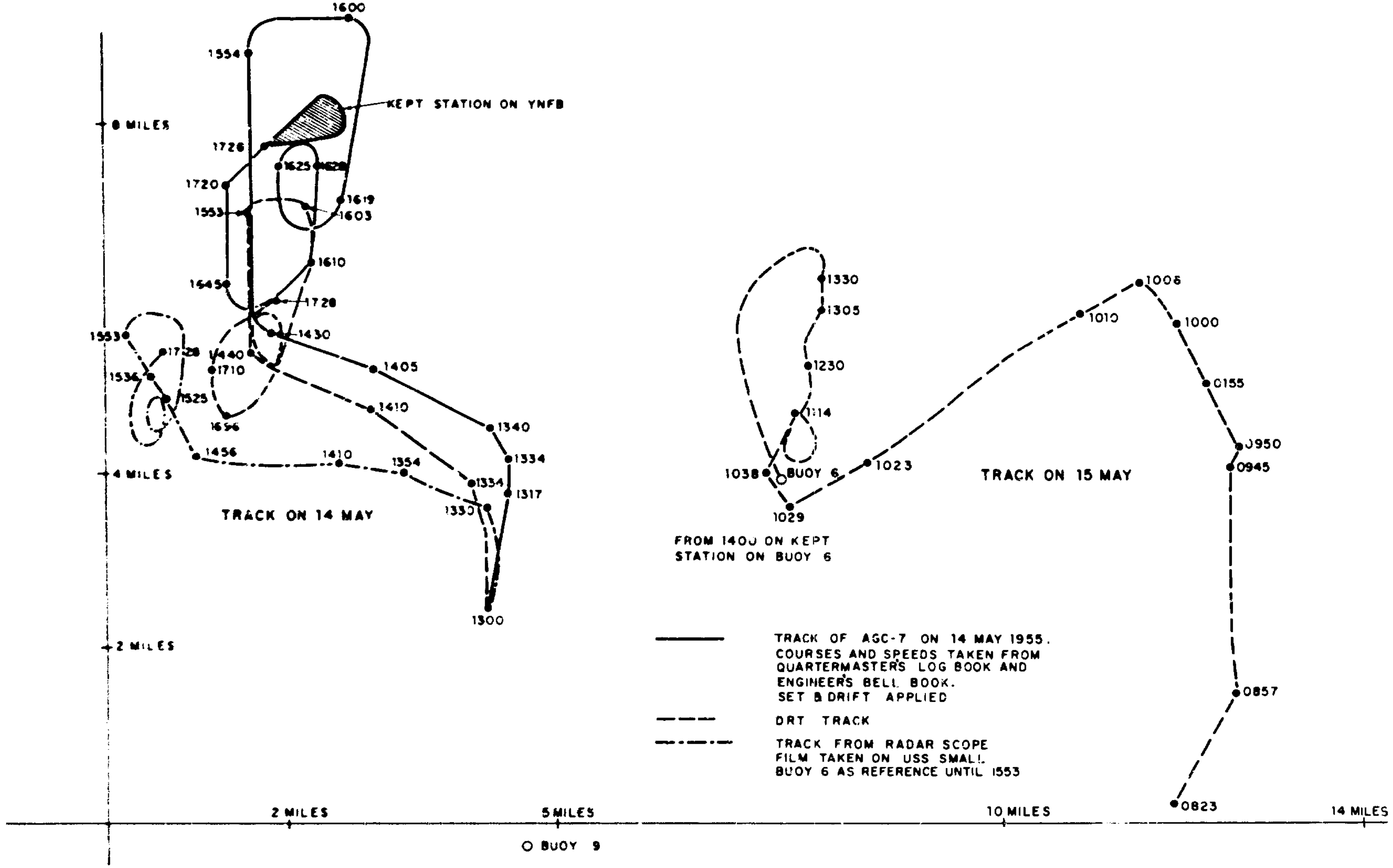


Fig. 2.2—Track of AGC-7 during Operation Wigwam.

area. The downwind portion of each pass could be extended to 5 miles from SZ at this time because the danger of airborne contamination was negligible. It remained possible (and desirable) for the pilot to use visual aids (rather than TACRON control) to establish his course across the area. After the Able series, external radiation dosages to personnel were negligible.

By late afternoon the contaminated area had increased considerably, and the "parallel-pass" flight plan was chosen for the Easy and Fox series. The dye was still visible in one area, but there were no navigational aids to indicate the center of the contaminated body of water. Some difficulty was experienced in finding the area by following directions from Program II Plot and TACRON, but once the dye was sighted the general area could be located. A run was made across the area to determine the approximate diameter of the contaminated water mass, and then the parallel-pass flight pattern was started.

On D+2 days an attempt was made to modify the parallel-pass pattern by changing the direction of the parallel passes to resemble spokes of a wagon wheel with AGC-7 at the center (the hub of the wheel). This modification was successfully achieved on D+3 days, and very good control and radar tracks were obtained on D+3 and D+4 days.

2.4.3 Control by TACRON and Aerial Survey Supervisor

The survey aircraft were controlled by a Navy TACRON unit which was located on AGC-7. The required flight plans were outlined to the TACRON supervisor by the aerial survey supervisor. These instructions, as well as all other operating instructions, were given to the pilot over the designated UHF channels. The TACRON unit tracked the survey aircraft by radar while the survey series were being executed and relayed this information to the Project 2.4 personnel for plotting. As the plots developed and additional operational instructions to the pilots became necessary, the aerial survey supervisor forwarded the appropriate information to the TACRON supervisor, who in turn relayed it to the pilot in the lead survey aircraft. The difficulties mentioned in the previous paragraphs are attributable to a misunderstanding as to whether course recommendations were given in "true" or "magnetic" bearings and to the plotting errors indicated below.

The aerial survey supervisor was in direct communication with the technical observer in the plane at all times. Channel Tare 5 was used for this purpose. Technical information regarding (1) the dosages to the aircraft crew and (2) event phenomena were relayed to the aerial survey supervisor as soon as possible. This very sharp division between the control of the flight operations of the aircraft and the technical operations, with a separate communications arrangement for each controller, reduced the confusion in the aircraft to a minimum and did much to improve the over-all efficiency of the operation.

2.5 POSITION PLOTTING

During all traverses of the contaminated areas by YAG-39 and YAG-40 and aerial survey aircraft, a continuous plot of the tracks was maintained in the Program II Plot on AGC-7. This plot was obtained from the ranges and bearings taken from the surface- and air-search radar on AGC-7. On D-day, AGC-7 was to maintain station on a fixed buoy after H-hour, which would eliminate any plotting errors while tracing the test ships. Because of the weather conditions the buoy was never set out, and, after H-hour, AGC-7 steamed away from her H-hour position. Operationally this caused considerable confusion and frustration.

For purposes of this report, a track of AGC-7 had to be derived to obtain the "accurate" tracks of YAG-39 and YAG-40 and aerial survey planes relative to SZ. This track is given in Fig. 2.2 and was constructed from information obtained from the radar photography taken on the surface-search radar on the DD (USS Small) and from the quartermaster log book and Engineers Bell Book on AGC-7.

After noon on D+1 and D+2 days, AGC-7 maintained station on Buoy 6 which was moored by SIO previously to H-hour. The position of Buoy 6 was confirmed from radar photography. On D+3 days, AGC-7 maintained station on Buoy 9, which was moored by SIO on D-day, and its position was determined from ranges and bearings to Buoy 6.

CHAPTER 3

AERIAL SURVEY

By M. B. Hawkins, W. S. Kehrer, R. Graveson, J. E. Howell, and F. K. Kawahara

3.1 OBJECTIVES

As previously indicated, the aerial survey problem was operationally a joint responsibility of Projects 2.1 and 2.4. The over-all objectives of this coordinated effort were as follows (organizations primarily interested in the data are shown in parentheses):

1. To obtain, at very early times, observed and recorded information relative to the surface phenomena and the radiological situation so that operational implementation of Program II and other programs could be accomplished safely and expeditiously (Program II Directors, CTG 7.3, Project 0.17, and Project 2.4).
2. To obtain observed and recorded information relative to the surface and near-surface phenomenology associated with an underwater nuclear detonation (Project 2.1 and Project 2.6).
3. To obtain information for determining the radiological hazards associated with such use of nuclear weapons in tactical situations (Project 2.4).
4. To provide for the dropping of samplers for collecting contaminated water at very early times after detonation (Project 2.1).
5. To evaluate the adequacy of the equipment and instrumentation for experimental and/or tactical use (Project 2.4).

The accomplishment of objectives 1 and 3 required that the following data be obtained, some at early times only and others continuing until D+4 days (Project responsibility is indicated in parentheses):

1. The size, configuration, and location of the contaminated area or areas (Project 2.4*).
2. The extent and distribution of the contaminant in the area as measured by the radiation field in and over the area (Project 2.4).
3. The temperature of the water in and about the contaminated and associated areas (Project 2.1).
4. The spectral distribution of the gamma photons emitted by the contaminated water (Project 2.4 and NYOO-AEC).

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*Operation and reporting responsibility was to be transferred to Project 2.1 when radiation intensity had lessened to levels not tactically significant.

3.2 INSTRUMENTATION

The instruments used by Project 2.4 were:

1. The NYOO-AEC aerial survey equipment.
2. The Bureau of Aeronautics USQ radiac telemetering detectors.
3. The NYOO-AEC gamma spectral apparatus.
4. Radar and associated position-plotting gear on various Task Force ships.

3.2.1 NYOO Aerial Survey Equipment*

The Health and Safety Laboratory (HASL) of the New York Operations Office, AEC, provided and maintained the radiation-detection equipment and operated the telemeter installation in the Program II Plot.

The gamma-radiation flux from the radioactive products dispersed in the sea, whether disposed locally or deposited by fall-out, can be measured in an aircraft above the area. The dimensions of the contaminated area, found under these conditions, are such that the gamma radiation appears to come from an infinitely large source. Thus the intensity of the radiation is mainly reduced by absorption in the interposed layers of air. The profiles of the radiation field, measured during aircraft flights across the area, show gradients and intensities directly relatable to the surface layer of the sea. However, the absorption of the radiation by the water limits the measurements of gamma radiation to a thin top layer.

The NYOO-AEC aerial survey equipment detects and records gamma radiation. This measurement in the aircraft is automatically and continuously compensated to the reading which would have been detected at 3 ft from the surface. The compensated data are telemetered to a central receiver located at a plot center. The radiation data, when correlated with plane position, may be displayed on a plot board to show the contaminated area. The basic sections of this system are shown in Fig. 3.1.

(a) Gamma Detector. The "Top Hat" gamma detector and its associated control box utilize an internal dry-battery power supply. The detector section is hermetically sealed to resist humidity-induced variations. It was mounted in the tail section of the aircraft. In this position the radiation measurements were not influenced significantly by radioactive dial instruments in the pilot's compartment nor by in-flight contamination. To further reduce the influence of radioactivity carried by the aircraft, the top and sides of the detectors were surrounded by a lead shield inside the Top Hat. The detectors look down out of the aircraft through an aperture described in Fig. 3.2. Besides these factors, the mounting position was selected to minimize absorption of the gamma radiation by the aircraft structure. For this operation the detector was adjacent to the thin aluminum skin of the aircraft, which has negligible absorption.

Figure 3.3 shows the aerial survey equipment in the aircraft, including the control box, radio junction box, and the strip-chart recorder which records the radiation level at the aircraft. The Top Hat control box includes a scale selection switch, an altitude control switch (so that the operator may manually introduce the altitude correction factor in the event of radar altimeter failure), and a meter that reads the radiation compensated to an equivalent surface intensity. The radio junction box allows the operator either to telemeter the compensated radiation data automatically or to use the radio channel for two-way voice communication with the Program II Plot.

The detector employs two gamma-radiation-sensitive plastic phosphors and two photomultiplier tubes. Both feed a common scintillation integrator circuit. Section 1 responds linearly to gamma-radiation intensities from 0.005 to 100 mr/hr. Section 2, by means of a smaller phosphor, responds from 10 mr/hr to 200 r/hr. Thus there is an overlap of one decade of radiation intensity between the two sections. The electronic circuit converts this

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*Detailed description of the equipment will be found in a forthcoming NYOO-AEC document, Top Hat Aerial Survey System.

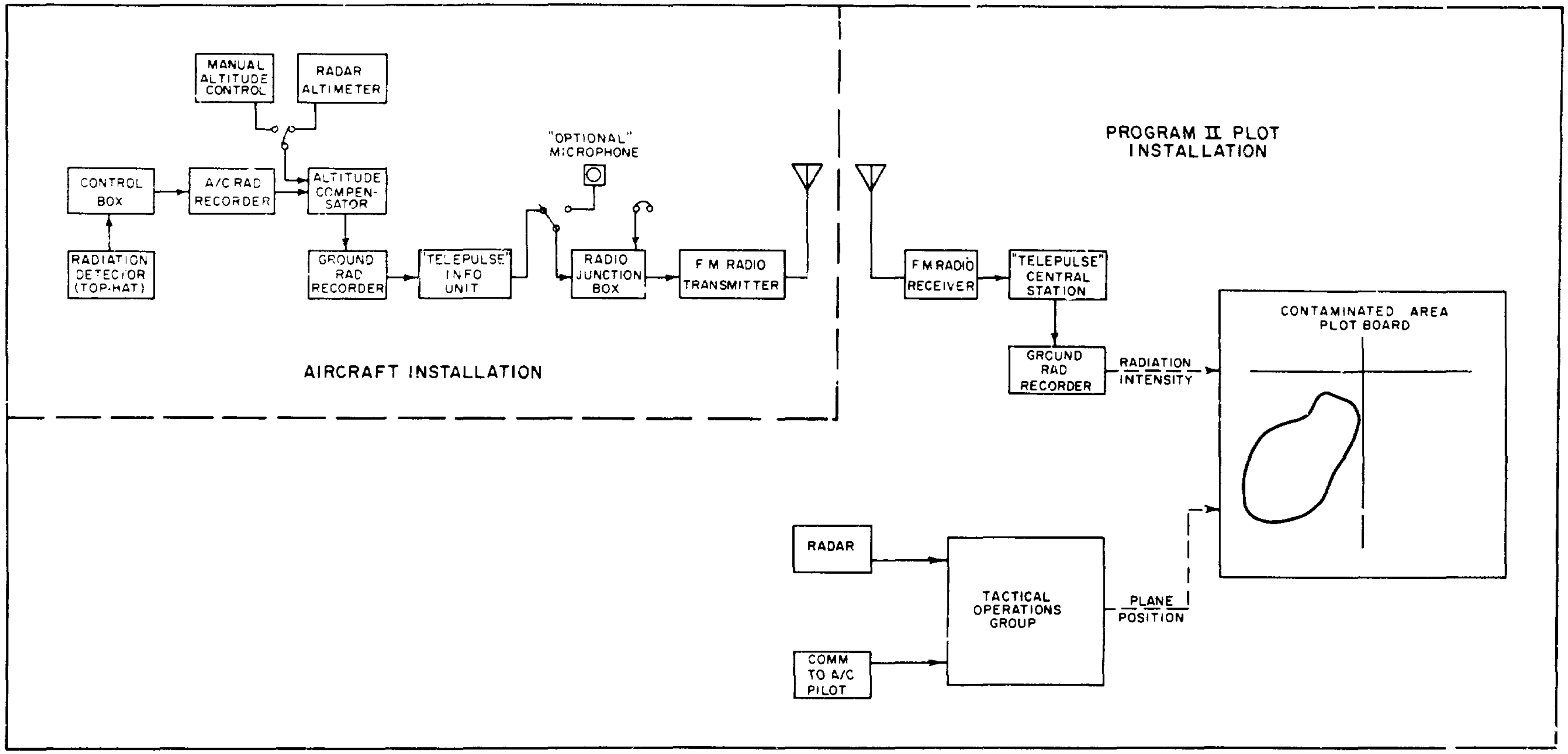

Fig. 3.1—Block diagram of NYOO-AEC aerial survey equipment.

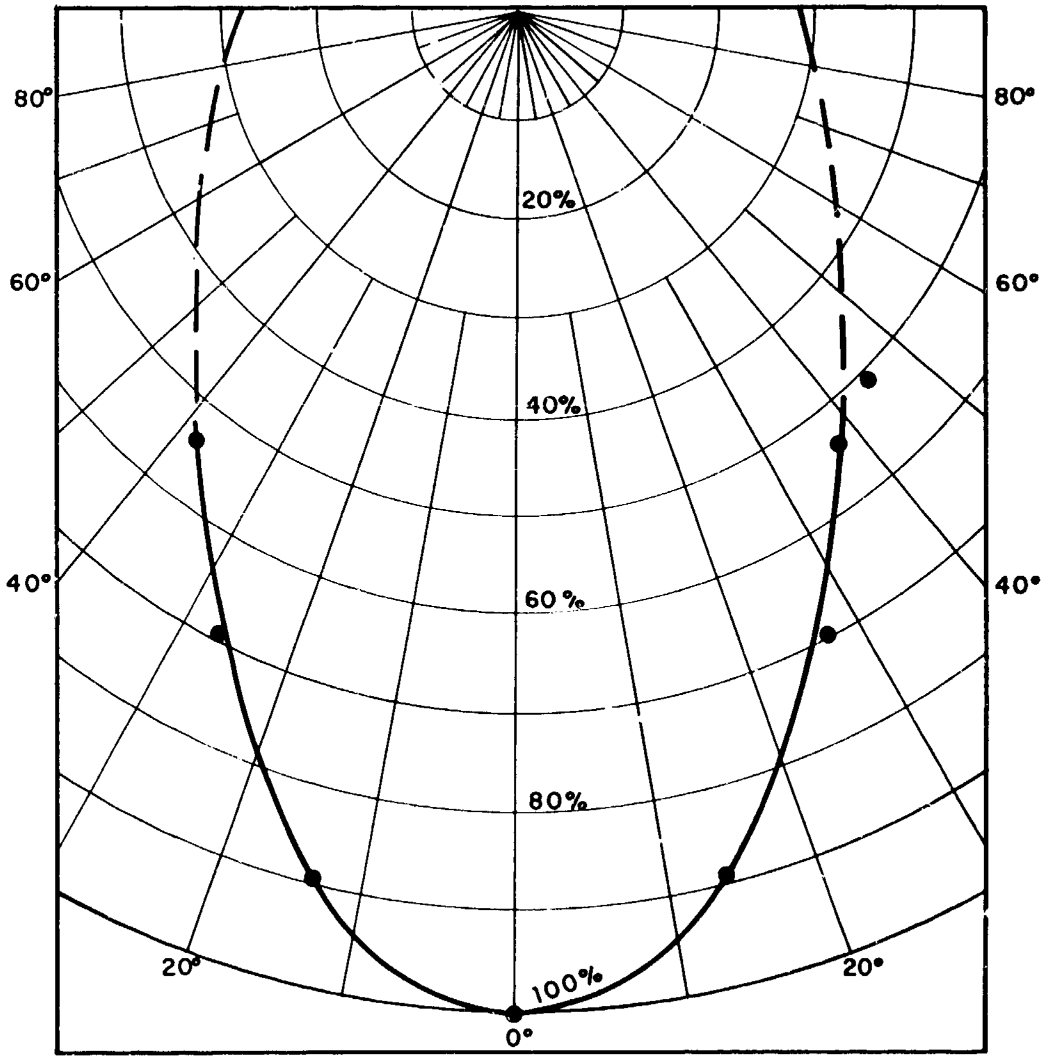

Fig. 3.2—"Top Hat" angular response.

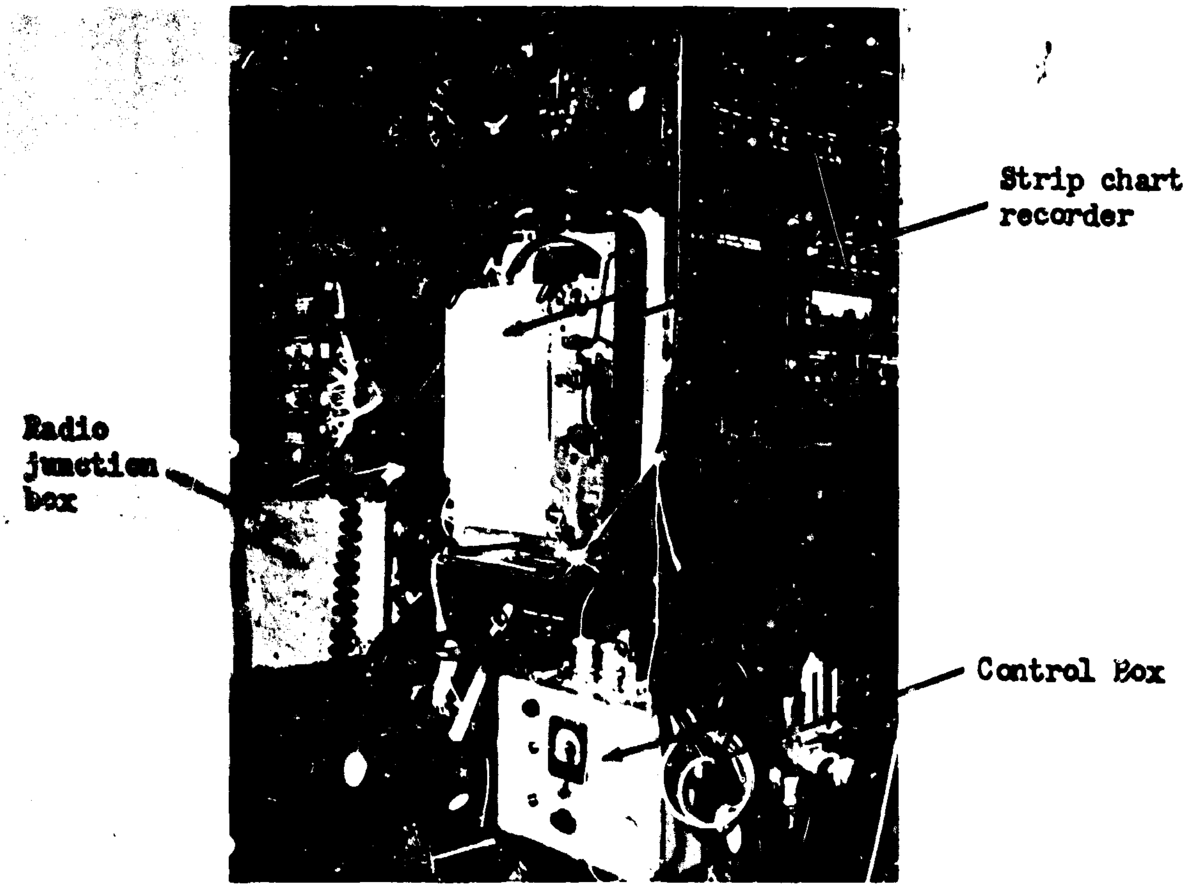

Fig. 3.3—Aerial survey equipment in the aircraft.

linear response to a logarithmically described output current which is used to deflect the pen of a strip-chart recorder. This reading is the radiation intensity at the aircraft.

The plastic phosphor of Section 1 is 3 in. in diameter by 4 in. long and is optically coupled to a 3-in.-diameter Du Mont photomultiplier. Plastic phosphor of Section 2 is 1 in. in diameter by $^1/_4$ in. long and is used with a $1^1/_4$-in.-diameter Du Mont photomultiplier. The plastic phosphors were selected for their mechanical simplicity and their close approximation to gamma-energy independence. The phosphors, photomultipliers, and electronic circuit are housed in the hermetically sealed Top Hat.

The current from the detector circuit develops a voltage across the aircraft radiation-intensity recorder. This voltage, which is a logarithmic function of the incident radiation, is fed to a four-position switch and a biasing network. The switch, by selecting either of the two detector sections and proper bias, divides the total calibration (from 0.005 mr/hr to 200 r/hr) into four scales covering three decades each, as follows:

Scale A, 0.005 to 1.0 mr/hr
Scale B, 0.1 to 100 mr/hr
Scale C, 0.01 to 10 r/hr
Scale D, 1.0 to 1000 r/hr

Each scale overlaps the adjacent scales by one decade, thus providing regions of common coverage. The scale for a particular survey is selected to provide maximum scale utilization.

The absorption of gamma radiation from radioactive debris as a function of aircraft altitude closely approximates a logarithmic function. The radar altimeter (APN-22) on the AD-5N aircraft was supplied with a conversion potentiometer to supply a voltage directly proportional to altitude. This is electrically added to the logarithmically described radiation intensity. Mathematically, the sum of these logarithmic functions is equal to the product of radiation intensity in the aircraft and the altitude correction factor. The resultant voltage is a measure of the radiation that would have been measured at 3 ft from the surface. The altitude-compensated radiation intensity is recorded by a second strip-chart recorder mounted in the aircraft.

(b) Survey Unit Calibration. The nominal radiation calibration of the Top Hat detector is divided into two scales, one for each section of the unit. The detectors were adjusted before the test to the nominal curves by calibration in known radiation fields.

During Operation Wigwam, radiation sources of sufficiently high intensity for recalibration of the C-D scale were not available. Therefore these scales were initially set at the Nevada Test Site, and careful calibrations were performed when the units were returned to HASL, New York. The results of the pretest and posttest calibrations are included as Fig. 3.4. Although the posttest calibrations deviate from the original curves, it is assumed that they are the most accurate, and therefore they were used for the final computations.

The radiation intensity measured at the aircraft may be related to the radiation intensity at 3 ft from the surface. The correction factor is based by NYOO-AEC on measurements made during previous operations. These data vary with altitude and may be related to air absorption of radiation from an infinitely broad source.

During the George and How series, passes were made over the same location at varying altitudes. In addition, a helicopter obtained radiation data, as a function of altitude, over a smoke flare dropped in the contaminated area. The radiation readings are shown in Table 3.1. These readings were plotted and then extrapolated to a 3-ft value, and altitude factors were derived as indicated in Fig. 3.5.

The data for NR-92 on the How series appear suspect since they had agreed with NR-82 on the George series. In any case the data indicate a lower absorption than the NYOO-AEC's previous data. Altitude correction factors, based on data from previous operations, were used instead of deriving new factors. The previous data were based on more extensive experimental effort and were considered more reliable. Referring to Fig. 3.5, it is possible that the radiation intensities reported for the 3-ft altitude on D-day (from the survey flights at a 500-ft

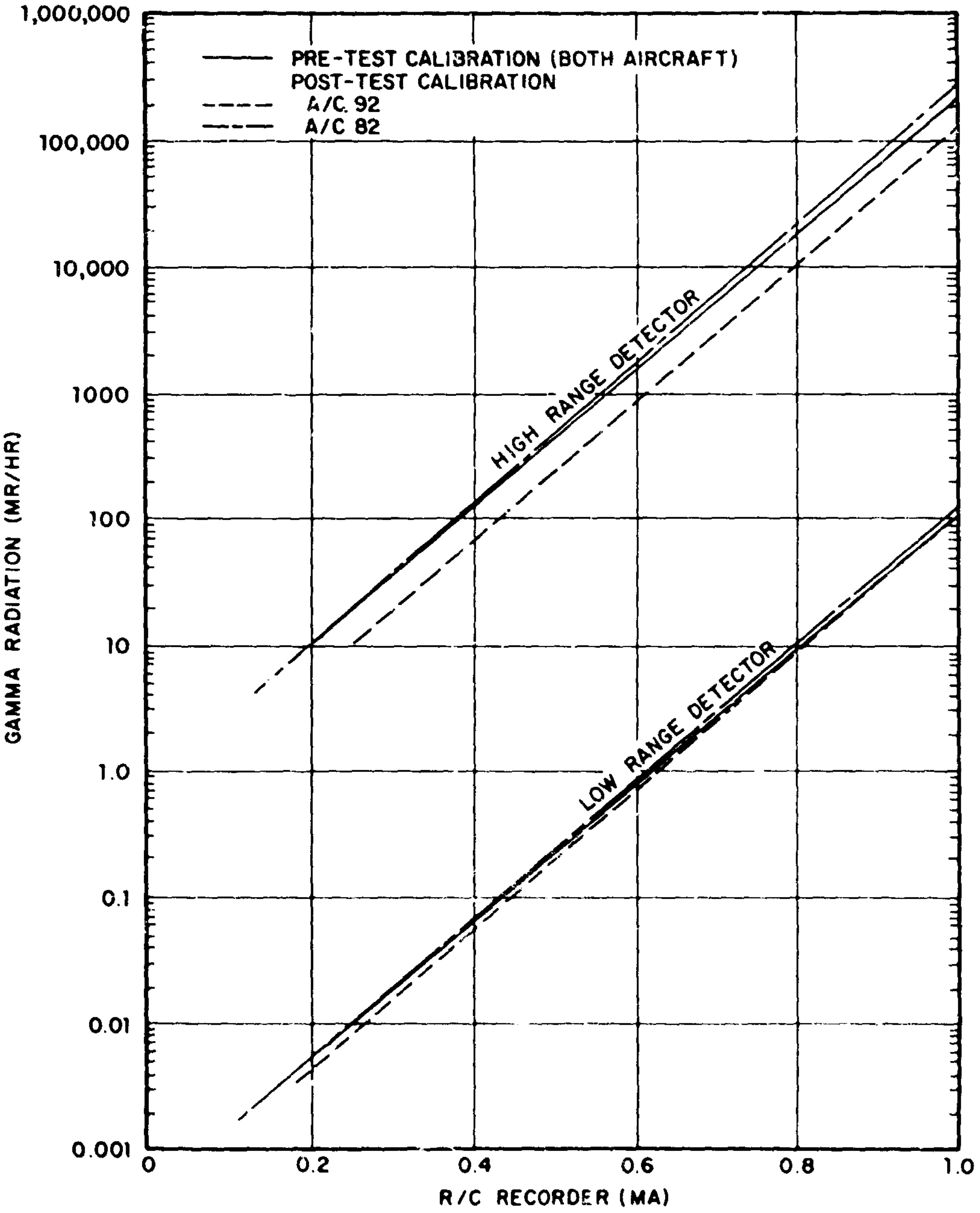

Fig. 3.4—"Top Hat" gamma calibration.

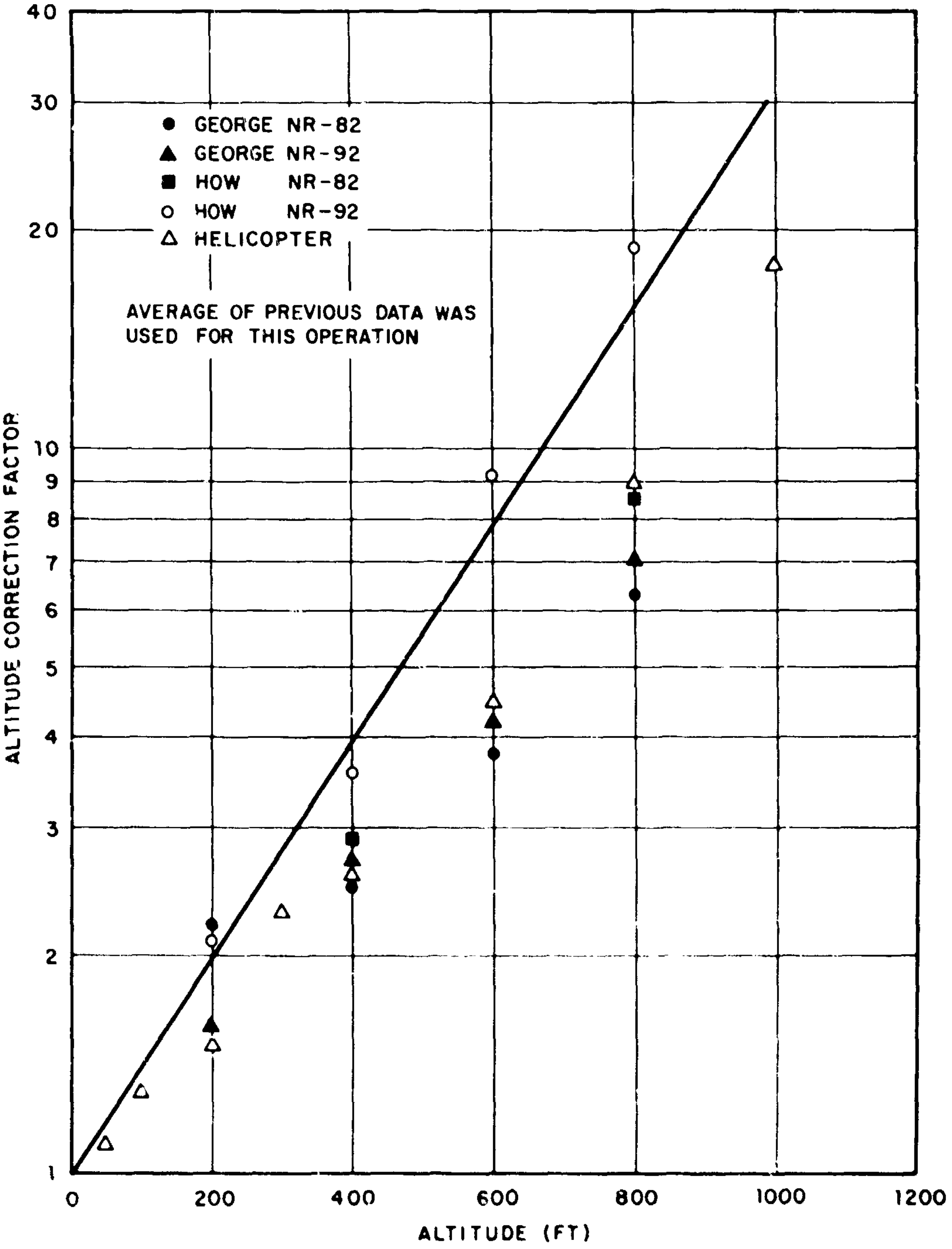

Fig. 3.5—Comparison of altitude correction factors on D+1 day.

Table 3.1 —MAXIMUM RADIATION INTENSITY, IN MILLIROENTGENS PER HOUR, AS A FUNCTION OF ALTITUDE

	George series		How series		
Altitude, ft	NR-82	NR-92	NR-82	NR-92	Helicopter
1000					5
800	6.2	6.4	5.1	1.8	10
600	10	10.5		3.8	20
400	15	17.0	15	9.6	35
300					40
200	17	28.5		16.7	60
100					72
50					83
3-ft extrap.	(37.5)	(45)	(44)	(35)	(90)

altitude) may be about 50 per cent too high and subsequently (from the survey flights at 200 ft) may be about 25 per cent too high. No attempt was made to establish the variation of correction with energy as reflected by time after detonation.

(c) "Telepulse" Telemetering System. The Telepulse information unit mounted in the aircraft converts the surface radiation-intensity reading to a form which can be transmitted by radio to a central location. The information unit is divided into four sections: aerial coupling unit, converter, comparator, and power supply. At the central plot the data are received, decoded, and converted to a reading on a strip-chart recorder. The system converts the d-c voltage across the recorder to a time-based pulse train. The number of pulses within each cycle of the train is proportional to the input voltage.

The aerial coupling unit contains a voltmeter bridge circuit to accept the 1-volt variation of output from the Top Hat circuit. This output is used to drive both the control-box meter and a strip-chart recorder (Esterline-Angus Co., model AW). This record is related to the radiation intensity at the surface. A relay circuit, controlled by a push button at the observer's position, introduces a full-scale deflection to the recorder for marking purposes.

The converter accepts a voltage from the bridge which is proportional to the recorder reading and produces an amplitude-sensed pulse train of 120 pulses/sec. This pulse train is in turn transformer coupled to the comparator section. There the input is converted to a time-based pulse train wherein the number of pulses per cycle is proportional to the amplitude of the input. This varies from 5 to 90 pulses within a 1-sec cycle when the input d-c voltage is changed from 0 to 1.4 volts.

The Telepulse information unit is coupled to the microphone input of a radio transmitter. During Wigwam the radio link consisted of two Motorola model L41G transceivers per channel.

The central radio receivers linked to the aircraft transmitters are connected to the Telepulse central stations. These central stations are activated by the initial pulses of each cycle of the train. The succeeding pulses are counted by a step charger circuit. During the blank period in the train after the last pulse of the cycle, the integrated total is transferred to a strip-chart recorder. Then the alternate storage condenser is discharged and transferred to the step charger circuit to integrate the total of the pulses in the succeeding cycle of the train.

The Telepulse central stations, with their associated radio receivers, were installed in pairs in the Program II Plot, Fig. 1.6. Each was operated with four strip-chart recorders to produce duplicate data. One chart was used by the central operator for immediate operational information, and the three additional records were distributed to other project groups: HASL, NRDL, and SIO.

(d) Telemetering Correlation. A permanent record was made of the data transmitted by the Telepulse telemeter both at the sending and at the receiving end. The peak readings for

each pass as recorded on these strip charts have been compared (Fig. 3.6), and it is evident that the data are reproduced reliably within ±5 per cent of full scale.

Much of the deviation was traced to the power source for the information unit. This section was connected to the 28-volt supply of the aircraft, which, during operation, varied between wide limits.

3.2.2 Airdrop Radiac Telemetering System—General

The Bureau of Aeronautic's radiac telemetering system consists of a droppable radiac transmitting set, AN/USQ-1(XN-3), which detects, measures, processes, and transmits high-gamma-radiation data which are received in a readable form by the associated equipment, the radiac data receptor AN/ARR-29(XN-3). The system is also used to indicate the locale from which the radiation data are taken. Position indication is accomplished by interrogation of the transmitter by an AN/APS-33 or similar X-band radar set. This system is designed for making radiological surveys in areas of high gamma-ray intensity by dropping transmitting sets at various points within the suspected contaminated area, either land or water, locating them by radar beacon methods, and presenting their transmitted data at a receiving station normally located in an aircraft flying at safe distances from the radioactive area.

Description of Components and Experimental Plan. A separate report* covers the use and evaluation of these units during the pre-Wigwam tests as well as at the operation. The report also describes the components and their circuitry.

The radiation detector is a Geiger-Mueller tube. The normal range of the units is 0.5 to 500 r/hr. However, one-third of the units were modified for Operation Wigwam to cover a range of 250 to 3000 r/hr.

Eleven units can be operated simultaneously since each telemetering unit can be set at a different frequency.

The application or use of the system at Wigwam was nonconventional in that the data receptors and radar units had to be aboard ship rather than airborne.

The preshot-day trials indicated that the maximum range that could be received by the shipboard station was 5 to 6 miles. Radar reception was unreliable, and local interference made interpretations of signals difficult.

3.2.3 Gamma Spectra

A portable analyzer was designed by NYOO-AEC for measuring gamma-ray spectra in the field. When this analyzer is mounted in a helicopter, spectral data may be obtained while the helicopter is in the air above a contaminated area. There is great need for such information, since the altitude correction factors used in aerial surveying are dependent on air absorption and radiation scattering.

(a) Portable Gamma Spectrum Analyzer. This unit is based on a scintillation detector and a single-channel, automatically swept, pulse-height analyzer. Its light weight and small size make it suitable for automobile and helicopter operation. It requires a source of 28 volts but may be used on 12 volts with minor changes.

The detector uses a 3-in.-diameter by 3-in.-long sodium iodide–thallium iodide activated crystal and a 3-in.-diameter photomultiplier. Gamma photons impinging on such a crystal produce scintillations that are proportional in intensity to the energy of the captured photon. The photomultiplier converts the scintillations to a bundle of electrons. These electrons, when referred to a time base, appear as pulses, which are amplified in the multiplier section. The number of pulses of each height may be related to the intensities of the various gamma lines in the spectrum. The detector assembly is housed in a probe that is connected to the pulse-height analyzer by a 30-ft cable. During operation the probe is lowered from the helicopter so that the scatter of the incident gamma photons by the aircraft structure is minimized.

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* F. K. Kawahara and J. E. Howell, Field Test of Radiac Telemetering System, USNRDL Evaluation Report ER-3 of 30 November 1956 (Confidential).

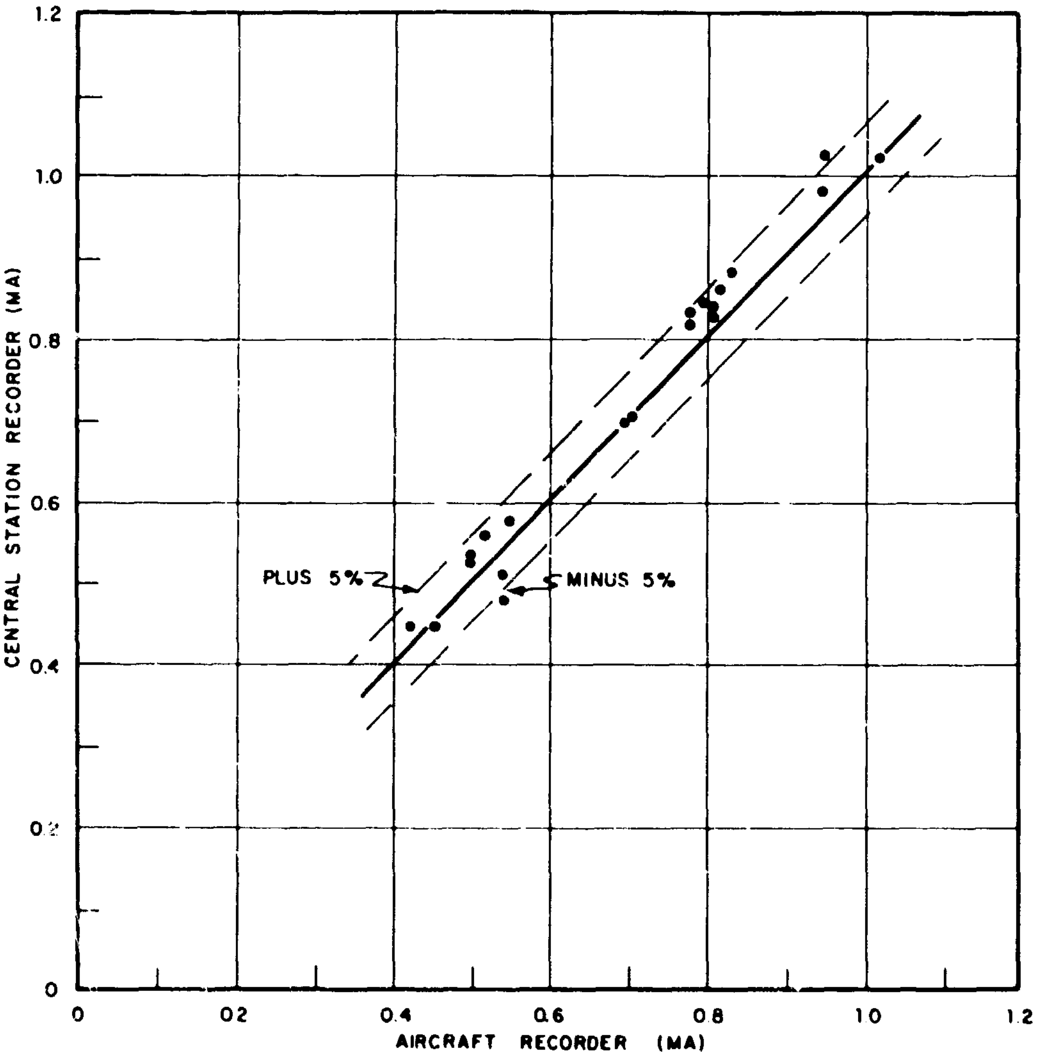

Fig. 3.6 — Telemeter correlation.

The single-channel pulse-height analyzer is based on fast electronic discriminator and gate circuits. All pulses that exceed the discriminator level (base-line control) trigger a gate and are counted at the output. However, a pulse that exceeds a preset level (slit-width control) after the discriminator not only triggers the first gate but also triggers a second gate which eliminates the transfer of the pulse to the output. Therefore only the pulses that exceed the discriminator level, and not the second trigger level, appear at a count rate circuit. At this point, the output pulse rate is determined and displayed on the Y axis of an X-Y recorder. The discriminator is automatically swept through the range of possible pulse heights. This sweep also drives the X axis of the X-Y recorder. Thus, for each momentary position of the X, or pulse-height axis, the count rate is recorded on the Y axis. Since pulse height is directly proportional to gamma energy, the intensity of each gamma line is automatically plotted.

The major difference between this and conventional techniques lies in the fast response of the discriminator and gate circuits. Over-all dead time between pulses is less than 100 mμsec. Therefore an efficient detector may be used to absorb a large number of gamma photons per second. In this way a small statistical deviation and a fast speed of response are achieved. Even in low (0.5 mr/hr) radiation fields, the full gamma spectrum may be analyzed and displayed in 1 min.

(b) Operational Experience. During Wigwam the analyzer was mounted in a helicopter. However, while hovering over the contaminated area, excessive vibration prevented the recorder from tracking. The recorder had operated satisfactorily during tests at Teapot; however, some of its internal connectors were not adequate for these severe conditions. No suitable substitute connectors were available at sea. The recording system will be modified and tested so that these data may be obtained on future operations.

The detector and analyzer responded properly, and some qualitative estimates of the relative spectra were possible by visual observation of the analyzer. In general, the spectra in the air above the contaminated area had most of their intensity at relatively low energies (<400 kev). Also, the spectra became progressively softer, i.e., they had lower energy components, as the altitude increased.

3.3 RESULTS AND DISCUSSION

3.3.1 Aerial Surveys

Each pass of the survey aircraft over the contaminated area resulted in a trace of the radiation intensity on a recorder in the aircraft, as well as the telemetered and altitude-compensated trace on recorders in the Program II Plot. The latter was used for operational purposes. For this report the original trace in the aircraft was manually corrected for altitude on the basis of the "previous data" curve, Fig. 3.5. The average intensity encountered during a pass was assumed to be the most satisfactory measure of hazard. Therefore the area beneath the curve as determined with a planimeter was divided by the total time to give the average intensity at 3 ft above the surface. This information is contained in Table 3.2.

For brevity, only the most significant (i.e., highest) information is included for each series and aircraft. Data from the various passes were utilized also to develop the shape and size of the contaminated area. At early times the high decay rate caused a considerable decrease in the radiation intensity between the first and the last pass of a series. Consequently the altitude-corrected trace was further corrected for the decay that took place during a series of passes. Thus Able-2 and Able-3 passes are decay-corrected to the time of start of Able-1 pass. A decay exponent* of −1.5 was used. Only D-day passes were decayed in this manner

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*The decay of mixed fission products appears to follow the function $R = R_0(t/t_0)^{-n}$. The exponent n is referred to throughout the report as the decay exponent. Other phenomena, such as the additive effect of radioactive decay and dilution of the water volume, that appear to follow a similar function are included in the value assigned this exponent.

Table 3.2 — PRINCIPAL AERIAL SURVEY RESULTS*
(Radiation Intensity at 3-ft Altitude)

		Survey 1 (NR-82)			Survey 2 (NR-92)		
Pass	Starting time,† hr	Average, mr/hr	Maximum, mr/hr	Length of pass, miles	Average, mr/hr	Maximum, mr/hr	Length of pass, miles
A-1	0.33	32,100	48,200	2.5	24,000	70,000	2.5
A-2	0.45	23,200	48,200	2.4	15,000	67,200	3.0
A-3	0.55	12,700	34,700	2.2	5,800	31,400	2.5
B-1	1.39	2,600	4,400	2.0	2,050	3,810	2.2
B-2	1.51	750	2,500	1.7		3,530	
B-3	1.57	1,400	3,190	2.2	1,200	2,580	2.2
C-1	1.73	1,300	2,600	2.4	1,150	2,300	2.5
C-2	1.87				275	1,570	1.1
C-3	1.96	400	840	1.7		896	
D-1	2.16				460	1,060	2.8
E-2	4.81	79	154	1.0			
E-6	5.09				238	336	2.4
E-8	5.21	172	258	2.2	224	314	2.3
E-10	5.34				217	297	2.3
E-3	4.87	6.0	16	2.8	Probably fall-out		
E-4	4.97	1.1	5.0	2.7			
E-5	5.02	1.4	4.5	2.5			
F-2	5.48	108	179	1.7	155	263	1.7
F-3	5.57				104	123	1.0
F-8	5.87	112	162	2.7			
F-9	5.97				98	151	1.4
G-1	19.47				36	66	2.5
G-2	19.52	34	69	3.5	42	95	3.6
G-13	20.47	57	128	2.6	38	102	3.6
G-14	20.57	47	98	3.3			
H-0	25.22	45	112	3.8	15	40	4.1
H-3	25.53				16	40	4.4
H-7	25.87	35	72	5.3			
H-9	26.03	50	92	3.4	19	40	3.5
I-0	44.45	8.2	16	3.1			
I-3	44.95				2.8	4.8	3.6
I-6	45.17	3.7	7.0	2.9			
I-9	45.49	3.6	7.4	3.5			
I-11	45.67				2.0	4.1	3.2
I-12	45.78				1.8	3.6	3.2
J-1	45.88	4.4	7.8	3.1			
J-2	45.97	3.6	7.0	3.5			
J-6	46.31	5.6	7.0	5.8			
J-7	46.38				2.7	4.8	3.0
J-8	46.46				2.5	4.4	1.6
J-12	46.81				2.2	4.4	5.9

* Data from only three passes per series are included; passes are those that have the largest "average intensity" during the series.

† The time after detonation at which the radiation field was intercepted.

since, after D-day, the decay was not rapid enough to introduce significant errors. Figure 3.7 indicates the data-handling technique.

Combining the radiation-intensity traces with the aircraft position plots allowed the development of the outline of the contaminated area (Fig. 3.8). The intensity of radiation at the outline of the contaminated area is 50 mr/hr at 3 ft above the surface for the Able and the Baker-Charlie-Dog series and 0.05 mr/hr for the remaining series. The plot of the Easy-Fox series shows both the 50 mr/hr and the 0.05 mr/hr outlines. These figures were chosen as being the minimum intensities that could be derived, taking into account the accuracy of the detection instrument on the two scales and the altitude at which the aerial survey flights were flown. The areas of the contaminated zones as measured by a planimeter are included.

The plot of Easy-Fox series in Fig. 3.8 indicates that the area inside the 50 mr/hr intensity outline had moved approximately 1 mile north and had decreased slightly in area. At the same time an area, estimated at 8 miles long by $2\frac{1}{2}$ miles wide, of less than 50 mr/hr intensity was indicated downwind to the southwest from the main body of the contaminant. This area had not been detected prior to the Easy-Fox series because the gamma-detector instruments were set on the high range scale. This activity was undoubtedly the residue of the fall-out.

Figure 3.9, taken from Table 3.2, indicates the variation of the average intensities (at 3 ft above the surface) with time. The line drawn through the "maximum" of the average intensities is assumed to be proportional to the maximum "hazard" for a traverse of the area at any time. This line appears to have a decay exponent of about −1.8.

(a) Detector Performance. During all flights (except on D+3 and D+4) both aircraft operated in a joint flight plan. The relation of peak radiation intensities measured by each aircraft on the same passes is shown in Fig. 3.10. Much of the variation was due to the uneven distribution of the contamination in the water. Since the aircraft often flew side by side, they did not view identical surface intensities. During the How series the readings deviate consistently by a factor of about 2.5, and it appears that one unit shifted calibration.

The aerial survey system consists of three major sections: detector, altitude compensator, and telemeter. Recorders were used at each of these sections, and comparison of their tapes allowed one to evaluate the sections separately. The detector performed well, and the measurements made in each aircraft correlate within the readability of the recorder scale. The operational characteristics and stability of the radar altimeter, however, were not completely satisfactory. Early data show effects of the unit recycling after sharp turns. Later surveys are not influenced since flight paths were longer and more nearly level. Telemetering reproduced the aerial data in the Program II Plot center within limits of 5 per cent. During the later phases of the operation, the radio range limits (17 to 20 miles) were barely adequate. For future operations, more powerful radio transmitters should be used so that longer distances could be covered.

(b) Plotting Performance. Many difficulties and sources of error were encountered in plotting the locations of the contaminated area. AGC-7, which carried the radar equipment used to track the aircraft, was in motion up to the time of the How series on D+1 day. Thus any error in the plotting of the track and location of AGC-7 was automatically reflected in the plot of the path of the aircraft, which in turn would result in an error in the location of the contaminated area. Also, the aircraft position was plotted from information on the radar screen or photographs of the radar screen, and the size of the blips of the aircraft limits their accuracy to about $\pm\frac{3}{8}$ mile. An examination of the plotted paths of the aircraft shows variations and discrepancies that could only be due either to errors by the radar equipment or to errors in reading the radar scope. For this reason the plots of the paths of the aircraft were sometimes altered, and sections of individual passes were shifted as much as 1 mile so that corresponding radiation intensities on intersecting passes would match. Because of the variations in the location of the aircraft from point to point on the radar plot, the speed of the aircraft was assumed to be a constant 150 knots or 253 ft/sec. This may be in slight error due to the influence of head winds, tail winds, cross winds, or variations in the indicated speed of the aircraft. Another source of error was the timing between the aircraft that

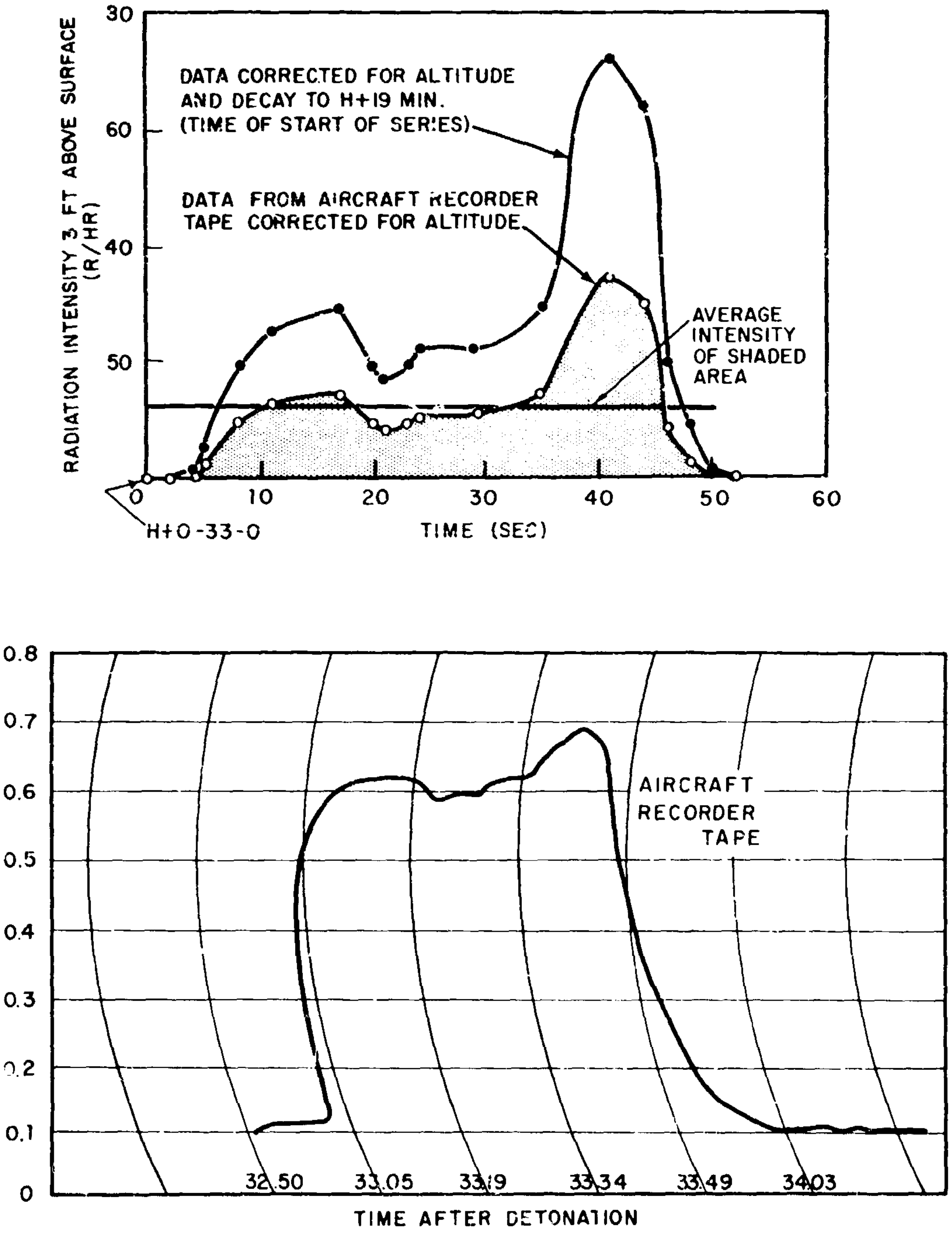


Fig. 3.7—Aerial survey data handling.

Fig. 3.8—(See page 28.)

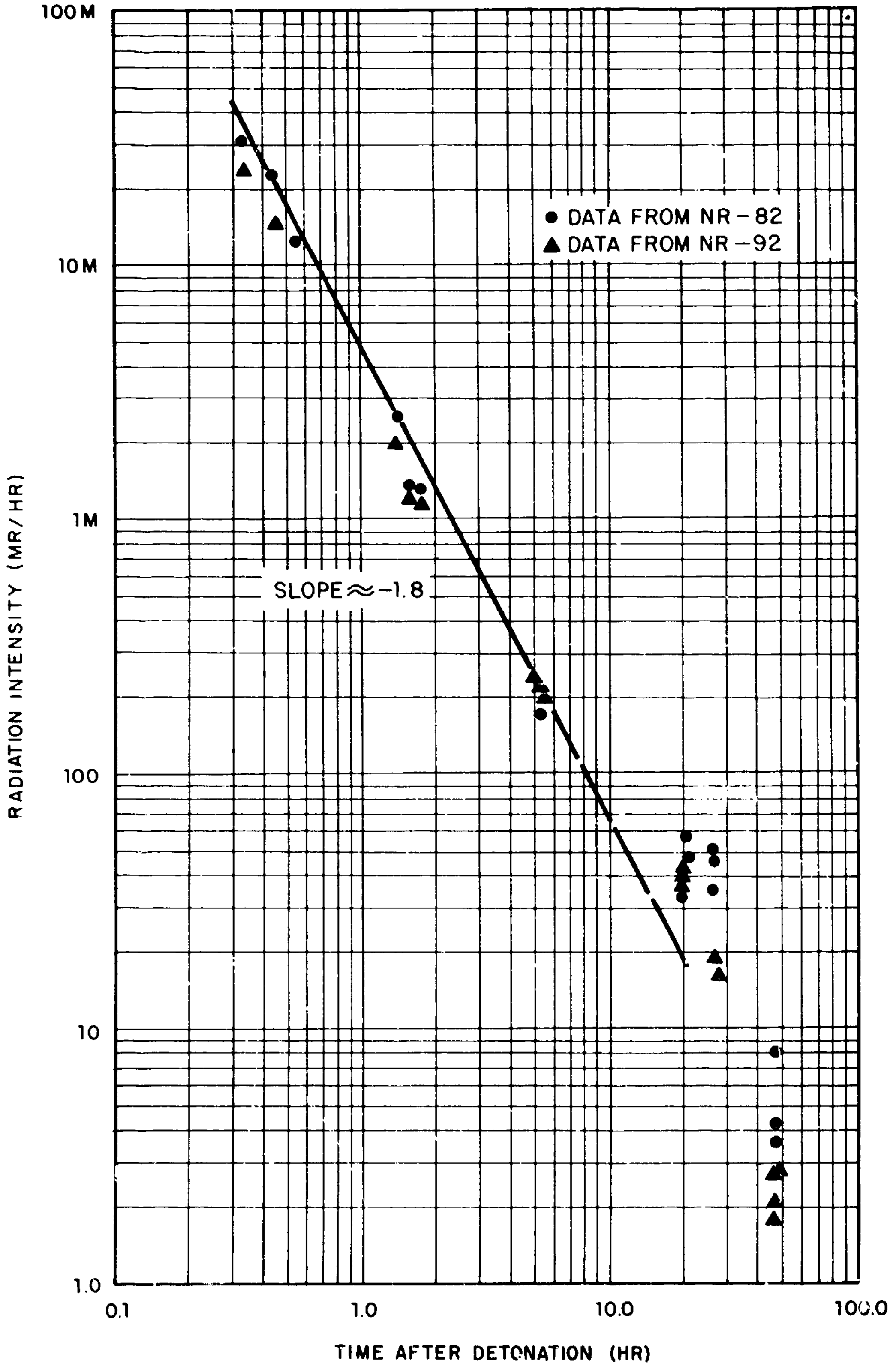


Fig. 3.9—Average radiation intensity 3 ft above the surface.

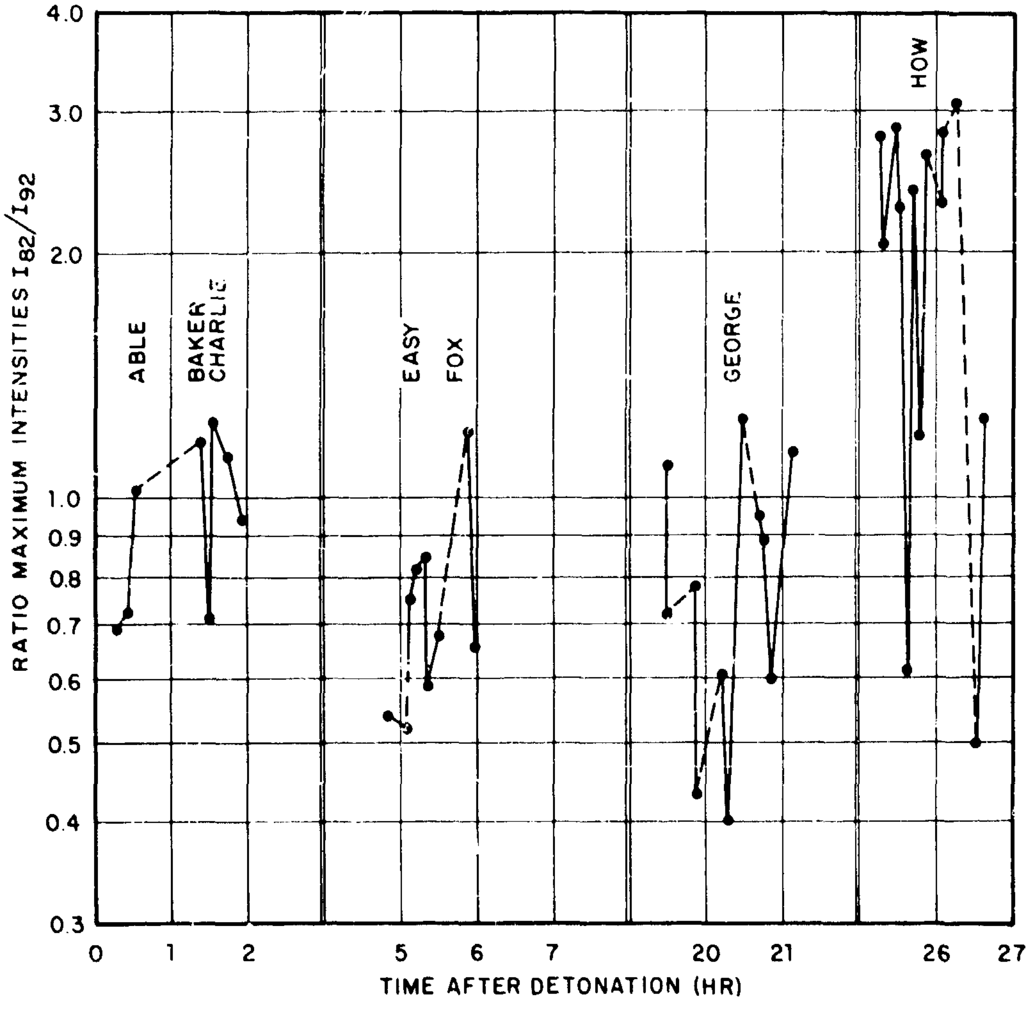


Fig. 3.10--Comparison of maximum intensities of NR-82 and NR-92.

carried the gamma-detector recording tape and the radar room of AGC-7. The maximum known difference was 75 sec during the How series on D + 1 day. A correction was made for this in plotting the contaminated area. There are also indications that at times the radar track was of the second aircraft and not the lead aircraft. In addition, the two aircraft switched positions on some passes, and this led to confusion.

Taking all these factors into account, it is still felt that the plots of the outline and location of the contaminated area are reasonably reliable and accurate to within ½ mile.

3.3.2 Radiac Telemetering System, AN/USQ-1(XN-3) and AN/ARR-29(XN-3)

The radiac data-telemetering system was an experimental model, and many shortcomings were expected. The system is normally used for surface-to-aircraft operation. The surface-to-surface procedure used during Operation Wigwam imposed operating conditions upon the equipment that were well beyond the original design specifications, particularly in reference to operating range and location determination. In addition, the recommended (AN/APS-33) radar was not available.

The first set of five radiac transmitters was dropped by the aircraft at about H + 26 min (Able-2 pass).

During the first half hour after the first five transmitting sets were dropped at Operation Wigwam, the receptor operators attempted to obtain reliable data at the primary station located in the AN/APS-15A radar room. Operational difficulties with the equipment required the utilization of the secondary equipment installed with the AN/SG-6B radar.

Of the original five units dropped, telemetering pulses were received from four units. Two of these units were of the high range (250 to 3000 r/hr) and under the conditions encountered could produce no data. One of the remaining units, Channel 3, transmitted intermittently for approximately 18 min, during which only three reliable readings were obtained. The radiation level shown by this unit at approximately 75 min after shot time was 14.5 r/hr. The remaining unit, Channel 7, produced consistent and apparently reliable data. No range and bearing information was obtainable.

The information obtained from a second Channel 7 transmitting unit dropped during Easy-10 pass compared quite satisfactorily with the first Channel 7 unit. Figure 3.11 shows the radiation field in the water as indicated on Channel 7 data vs time. The decay curve has an exponent of approximately −1.8.

Other units were dropped at various times on D-day and D + 1 day, but no useful data were obtained for various reasons.

Operational Summary. During the operation, 14 transmitting sets were dropped, and telemetered pulses were detected from 12 of these 14 units. Only seven of the 12 units were of low-range calibration, and continuous data were telemetered from only two out of the seven units. The other five units operated for less than 1 hr and yielded sporadic information. An evaluation of all mechanical and electrical components, as well as the watertightness of the transmitting sets, cannot be made since none of the units were recovered.

The basic principle of dropping radiac detectors into areas of high contamination and having the radiac information telemetered to stations remotely located from the contaminated area is considered sound and feasible, but the system as used in Operation Wigwam depended upon too many ideal conditions for the procurement of reliable data. The radiac telemetering system using the AN/USQ-1(XN-3) and the AN/ARR-29(XN-3) units was limited in range with the surface-to-surface method of operation. Some of the limiting conditions necessary for adequate surface-to-surface operation are:

1. Radio communications in the VHF (162–175 Mc) range, as well as radar sets in the same spectra as the USQ units, must be kept to a minimum, and certain high-power transmitters must be shut down during data-collecting periods to prevent spillover and interference.

2. The radiac receiving-station antenna for shipborne installation should be at least 300 ft above the water line. The installation imposes many design and construction problems for normal shipboard use.

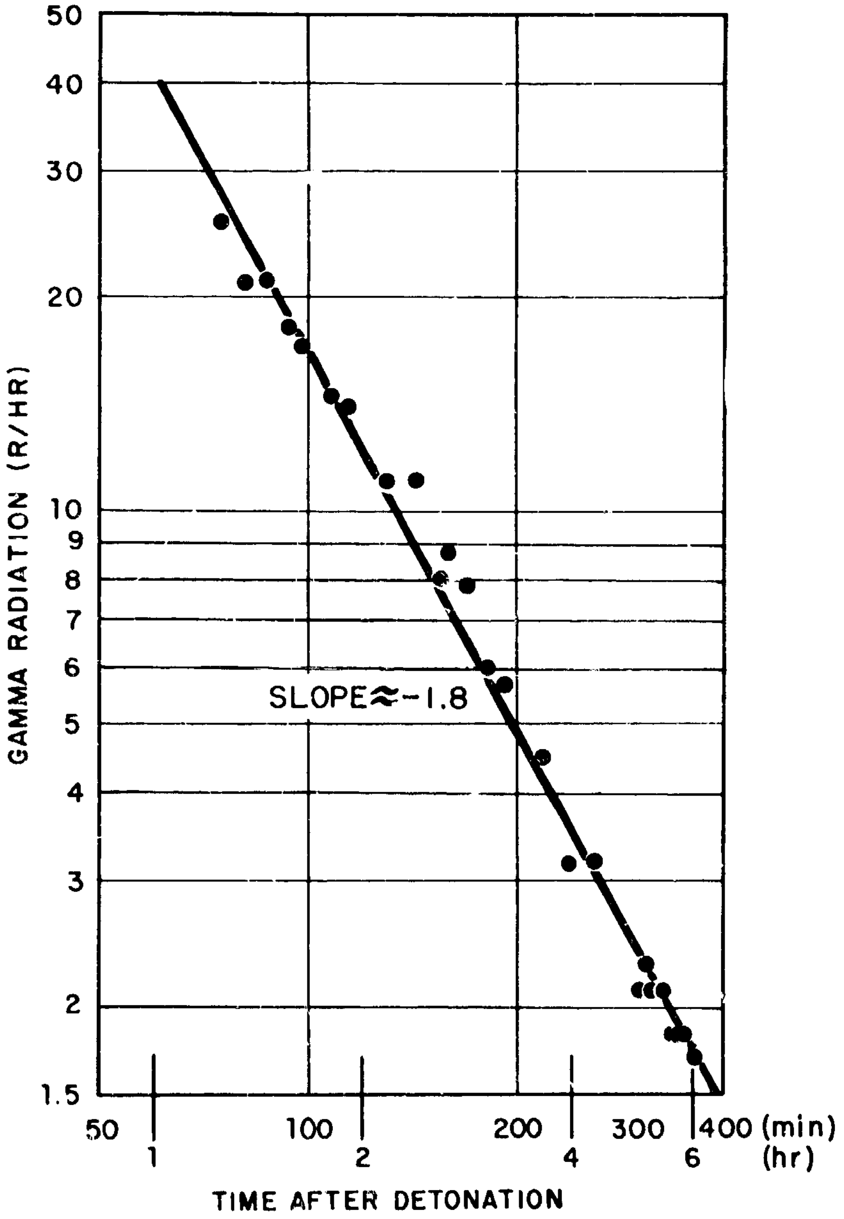


Fig. 3.11—Radiation field in water as indicated by radiac telemetering system.

3. The sea must be relatively calm.
4. Trained operators are required, and they must be assigned on a full-time basis.
5. The shipborne stations must be within 6 miles of the transmitting sets.

3.4 CONCLUSIONS

3.4.1 Operational

A study of the aerial survey results indicates the following conclusions:

1. An aerial survey is an effective method of obtaining radiation-intensity information as well as a rough outline and location of a contaminated area at any time after an underwater nuclear detonation within the limits of the detection instruments and radar equipment tracking range.

2. Considerable effort and man-hours are necessary to obtain a reasonably accurate outline and location of the contaminated area after the test has been completed. This includes (1) plotting the course of the ship; (2) plotting, from the radar data track, the course of the aircraft; (3) converting the data from the gamma-detector equipment to the proper form; and (4) outlining the contaminated area from this information.

3. The gamma-detector equipment used in the two planes was very sensitive and gave comparable results through noon of D+1 day. The results thereafter were different by a factor of 2 to 3. Considerable maintenance by a skilled technician was necessary to keep the instruments calibrated and operating properly.

4. The Bureau of Aeronautics radiac data-telemetering system for a surface-to-surface type of operation as used in Operation Wigwam can yield quick reliable radiation information to shipborne stations, provided that the ship is within 6 miles of the transmitting sets and a headphone set is used to hear the characteristic pulses.

5. Locating these transmitters is not feasible by the radar-beacon method beyond about 2 miles during a surface-to-surface operation. Further testing using the surface-to-surface type of operation as used in Operation Wigwam is not warranted.

3.4.2 Technical

Detonating conditions of the weapon at Operation Wigwam produced several radiological environments. (1) a contaminated water area due to the debris thrown out with the surface effects or upwelling of contaminated water from below, (2) a downwind cloud of airborne radioactive material, and (3) the residual fall-out from the cloud.

At the time of initial measurement (H+19 min) the contaminated water area was about $2^1/_2$ miles in diameter and had an area of 5.3 sq miles. The area was contaminated in an irregular manner, e.g., the peak intensities were approximately three times the average intensity. The average transit intensity across the area was about 25 to 30 r/hr 3 ft above the surface.

The radiation intensity decreased at a rate represented by an exponent of −1.8. Separate measurements indicated an actual radioactive decay exponent of −1.5.

The area circumscribed by a 50 mr/hr isointensity contour increased to 7.5 sq miles at H+1.4 hr. At H+4.2 hr it had decreased to 3.5 sq miles. Average transit intensities at these times were about 2 to 3 r/hr and 300 to 400 mr/hr, respectively.

Assuming that the decay exponent of −1.8 held at early times, the average transit intensity was about 3000 r/hr at H+2 min.

The downwind cloud was not measured by aerial survey. However, during the Easy-Fox series, when the minimum sensitivity of the detection instruments was changed to 0.05 mr/hr from 50 mr/hr, a contaminated area of relatively low intensity was discovered downwind from the main body of contaminant. The radiation intensity was about 1 per cent or less of that of the main area. Although the area might have been measurable during the Able series, no survey flights passed over the area. Flights were made over the area on the Baker-Charlie-Dog series, but the level was below 50 mr/hr. The general path and the low intensity of the area indicate that the area was undoubtedly a result of fall-out from the downwind cloud.

CHAPTER 4

SHIP HAZARD AND COUNTERMEASURE STUDIES

By F. S. Vine, Hong Lee, R. H. Black, R. J. Crew, and W. B. Lane

4.1 INTRODUCTION

At Operation Castle, investigations and evaluations were made of proposed decontamination procedures and other countermeasures for the radiological recovery of Navy ships. Inherent in these studies was the determination of the distribution of contamination, radiation dose rate, and radiation dosage throughout the ships as influenced by the radiological environments encountered. The countermeasures tested were the culmination of intensive laboratory, engineering scale, and field tests, the need for which had been demonstrated by the inconclusive results of the efforts to accomplish the gross decontamination of ships after the Crossroads-Baker test.

The data and information provided by Operation Castle permitted valid but limited conclusions to be reached. They also indicated a need for the further development and testing of an interim tactical decontamination procedure for ships and for the improvement of removable radiological protective coatings and a technique for the chemical stripping of standard Navy paint.

Furthermore, since the evaluation of the washdown countermeasure had been confined to the conditions pertaining to radioactive fall-out from a surface burst, the need to determine the extent of exposure of personnel to radiation from contaminated sea water delivered through the washdown system of a ship traversing a sea area contaminated by an underwater nuclear detonation became apparent. Associated with this situation was the possibility of radiation from an accumulation of significant amounts of radioactivity on the underwater hull surfaces and from the contaminated surface of the sea.

Past tests and other experimental work at the laboratory level have been seriously handicapped by a lack of valid correlation between the characteristics of laboratory-prepared simulants and those of the fission products from a nuclear detonation. It has been obvious that, in order to exploit the laboratory potential to the fullest, information providing this correlation was of immediate importance.

In recognition of the foregoing problems, appropriate studies were planned and organized for Operation Wigwam. The over-all administration and supervision of the project were the direct responsibilities of a deputy project officer. Each of the following subproblems was delegated to an individual problem leader who, in some instances, assigned separate tasks to other personnel under his supervision: (1) ship decontamination studies; (2) dose and contamination distribution studies, shielding effects, washdown evaluation, and radiological surveys; (3) contamination-decontamination studies, protective coatings and paint removal, and ship-bottom coatings; and (4) basic contamination-decontamination studies.

4.2 TEST LIMITATIONS AND DELETIONS

To meet all the objectives of the contamination countermeasure studies, it was necessary for YAG-39 to traverse the contaminated water area at early times with the washdown system in operation. Because YAG-39 was unable to do this, part of the planned objectives were not met. In addition, the ship decontamination studies, including the problem involving the chemical removal of paint, could not be performed because the ship was not contaminated to a sufficiently high level to make the necessary measurements.

4.3 INSTRUMENTATION

4.3.1 Fixed Gamma Intensity-Time Recorders (GITR)

The gamma intensity-time recorders,[1] so named to distinguish them from the portable radiac instruments, are permanently mounted electronic systems employing ionization chambers to provide continuous data of gamma intensity vs time. Radiation flux incident upon the ion chamber discharges preset automatic-recharging capacitors. Each cycle of the capacitors is recorded as an integrated-dose pulse mark on a roll of paper moving at a constant speed. Two to four detectors having different ranges were used at each instrument station. There were 20 stations on YAG-39 and 17 on YAG-40.

The modifications made for Operation Wigwam consisted of the relocation, reduction in number, and reduction in range of the detectors. In addition, the system components were removed from the ships, overhauled, and reinstalled. Table 4.1 shows the station locations for each ship and the type of detectors installed at each station. Table 4.2 shows the ranges of the detectors in the form of response times for gamma field intensities.

4.3.2 Gamma Surveys

Measurements of the gamma-radiation intensities were taken subsequent to contaminating events throughout the two test ships by survey teams (trained enlisted men) using AN/PDR-T1B radiacs.[2] The measurements were taken at predetermined locations to provide experimental data supplementary to those obtained from the fixed gamma time-intensity recorders. The weather-deck measurements were taken 3 ft above the deck surface, and the hold measurements were taken in contact with the interior hull surface.

Because the ship decontamination-procedure studies were canceled, YAG-40 was given only one complete initial survey, and YAG-39 was cursorily surveyed. No subsequent measurements were required.

4.3.3 Beta Surveys

Measurements of the beta-radiation intensity near contaminated surfaces were taken with USNRDL RBI-10 beta probes[3] modified to provide an extra "hi-lo" range switch and over-all physical strengthening of the instrument. These instruments have superimposed air ion chambers with opposed circuitry to eliminate the gamma ionizing effect. All measurements were made with the probe held against the surface at prespecified weather-surface locations.

4.3.4 Dosimetry Films

The cost of modifying and maintaining all the fixed gamma detectors originally aboard the two ships to supply dosage distribution data would have been prohibitive. Dosimetry films were therefore used in many locations in place of fixed gamma-detector stations.

Du Pont radiation dosimetry film packets, types 552 and 558, were selected. The usable over-all range of these films was from 0.1 to 500 r. They were calibrated with a cesium source prior to the operation; the test films were processed immediately upon being returned from the test site.

Table 4.1 — FIXED GAMMA INTENSITY-TIME RECORDERS

Station	Ship	Detectors*	Location and purpose
2	40	Am, Bm, Cm, Dm, Em	Keel, forward; sea contamination evaluation
7	40	Am, Bm, Cm	Hold 1, manifold space; space radiation level and entry†
9	39, 40	Am, Bm, Cm	Forward kingpost; washdown evaluation and radiation evaluation from distance
13	39	Am, Bm, Cm, Dm	Over Hold 2, main deck, starboard; deck contamination and shielding studies
13	40	Bm, Dm	Over Hold 2, main deck, starboard; deck contamination and shielding studies
14	39, 40	Bm, Dm	Over Hold 2, main deck, port; deck contamination and shielding studies
15	39	Bm, Cm, Dm	Over Hold 2, main deck, center; deck contamination and shielding studies
15	40	Am, Bm, Cm	Over Hold 2, main deck, center; deck contamination and shielding studies
17	39	Am, Bm, Cm	Over Hold 2 hatch cover, main deck; shielding studies
19	39	Bm, Cm, Dm	Over Hold 2 hatch cover, main deck; shielding studies
20	39	Am, Bm, Cm	Over Hold 2 hatch cover, main deck; shielding studies
22	39	Bm, Cm, Dm	Over Hold 2 hatch cover, main deck; shielding studies
23	39	Am, Bm, Cm	Over Hold 2 hatch cover, main deck; shielding studies
24	39	Bm, Cm, Dm	Over Hold 2 hatch cover, main deck; shielding studies
25	39, 40	Bm, Cm, Dm	3 ft below Hold 2 hatch cover, center; space dose and shielding studies
26	39, 40	Bm, Cm, Dm	1 ft above second deck, Hold 2, center; space dose and shielding studies
27	39, 40	Bm, Cm, Dm	Hold 2, 11 ft below second deck, center; space dose and shielding studies
28	39, 40	Bm, Cm, Dm	Hold 2, 22 ft below second deck, center; space dose and shielding studies
32	39	Am, Bm, Cm, Dm	Main deck, forward of superstructure, port; deck contamination studies
39	39, 40	Am, Bm, Dm	Wheelhouse; space radiation level and entry†
57	40	Bm, Dm	Engine room, aft; space radiation level and entry†
58	39, 40	Bm, Cm, Dm	Engine room, firing aisle; space radiation level and entry†
64	39	Bm, Dm	Recorder room; space radiation level and entry†
64	40	Bm, Cm, Dm	Recorder room; space radiation level and entry
67	39, 40	Bm, Cm, Dm	Over Hold 4 hatch cover, main deck, starboard; deck contamination studies
68	39, 40	Bm, Cm, Dm	Over Hold 4 hatch cover, main deck, port; deck contamination studies

* See Table 4.2 for definition.

† Used to determine times for safe entry and staying times, regarding operational radiological safety.

Table 4.2—DETECTOR RANGE AND RESPONSE

Field, r/hr	Response,* sec				
	Am	Bm	Cm	Dm	Em
0.001	3,600				
0.002	1,800				
0.005	720				
0.010	360	3,600			
0.020	180	1,800			
0.036	100	1,000			
0.050	72	720			
0.100	36	360	3,600		
0.200	18	180	1,800		
0.360	10	100	1,000		
0.500	7.2	72	720		
1.00		36	360	3,600	
2.00		18	180	1,800	
3.60		10	100	1,000	
5.00		7.2	72	720	
10.0			36	360	3,600
20.0			18	180	1,800
36.0			10	100	1,000
50.0			7.2	72	720
100				36	360
200				18	180
360				10	100
500				7.2	72
1 000					36
2,000					18
3,600					10
5,000					7.2
	Dose, mr/mark				
	1	10	100	1,000	10,000

* "Response in seconds" is the time lapse between each recorder pulse mark on a continuous roll of data paper.

The films on weatherside stations were mounted 3 ft above horizontal surfaces in brackets that allowed 4π geometry. In the interior of the ship they were located against convenient bulkheads and existing structural members of shipboard equipment.

4.3.5 Cross Calibration

The total accumulated doses on gamma intensity-time recorders and dosimeter films located at the detector stations on YAG-39 were individually compared, and the former were found to be less by factors of 0.72 to 0.91. A similar comparison of the measured doses on YAG-40 was less consistent. The ratios of weatherside station measurements ranged from 1.3 to 1.5, and the ratios of internal measurements ranged from 0.71 to 1.04.

4.4 DOSAGE AND CONTAMINATION DISTRIBUTION

The objective of the dosage and contamination distribution study was to determine the distribution of radiation dosage and radioactive contamination aboard the test ships, particularly as related to radiological environments of tactical interest.

4.4.1 Experimental Plan

It was planned that, immediately after the underwater device was detonated, YAG-39 with its washdown system activated would pass through the fall-out and then follow YAG-40 through the contaminated area. The fixed gamma detectors, dosimeter films, and surveys taken with portable beta and gamma instruments were to provide dosage and contamination distribution information.

4.4.2 Results and Discussion

(a) YAG-39 Data. At H+13 min, at a location about 200°T and 9800 yards distant from SZ, YAG-39 encountered an invisible cloud of airborne radioactive material. The washdown system was in operation. YAG-39 encountered no other radiological environments on D-day. On D+1 day the ship steamed through the contaminated water area, again with the washdown system operating. The gamma-radiation intensities recorded during these events by the GITR on the kingpost is shown in Fig. 4.1. Location of the ship relative to SZ is shown in Fig. 2.1.

The cloud encountered by YAG-39 gave radiation-intensity readings in excess of 400 r/hr at H+16 and H+19 min. The radiation field fell off rapidly at about H+22 min to about 1 r/hr. Residual contamination was left on the ship, but decay and the washdown system reduced the radiation levels quite rapidly. The dose rate at various stations on the ship during the critical period is shown in Fig. 4.2.

At H+1 hr the average gamma intensity on the weather decks was about 9 mr/hr.

By H+2 hr the beta activity was extremely low and could not be measured with the USNRDL RBI-12 beta probes. There was no detectable contamination of the ship's interior, although a water leak was found at the expansion joint between the ventilation deckhouse and the main superstructure. Slight contamination was indicated, however, in various sea-water cooling systems and in the washdown main trunk lines and pipelines.

The dosage accumulated on the weatherside deck of the ship during the first 20 hr after detonation was indicated by dosimetry films as about 30 r. On the open, unobstructed deck, values ranged from 26 to 35 r. Films in the gun tubs indicated 23 and 26 r. Figure 4.3 shows the dose distribution throughout various areas of the ship. In the interior of the ship, immediately below the contaminated weather surface, the total dose was reduced by a factor of 3. Centerline measurements on the next succeeding deck showed an additional reduction by a factor of 2.

Centrally in the superstructure at the main-deck level, the total dose was 1.5 r, only 5 per cent of the topside dose. The engine-room lower level beneath the superstructure received only 0.5 r.

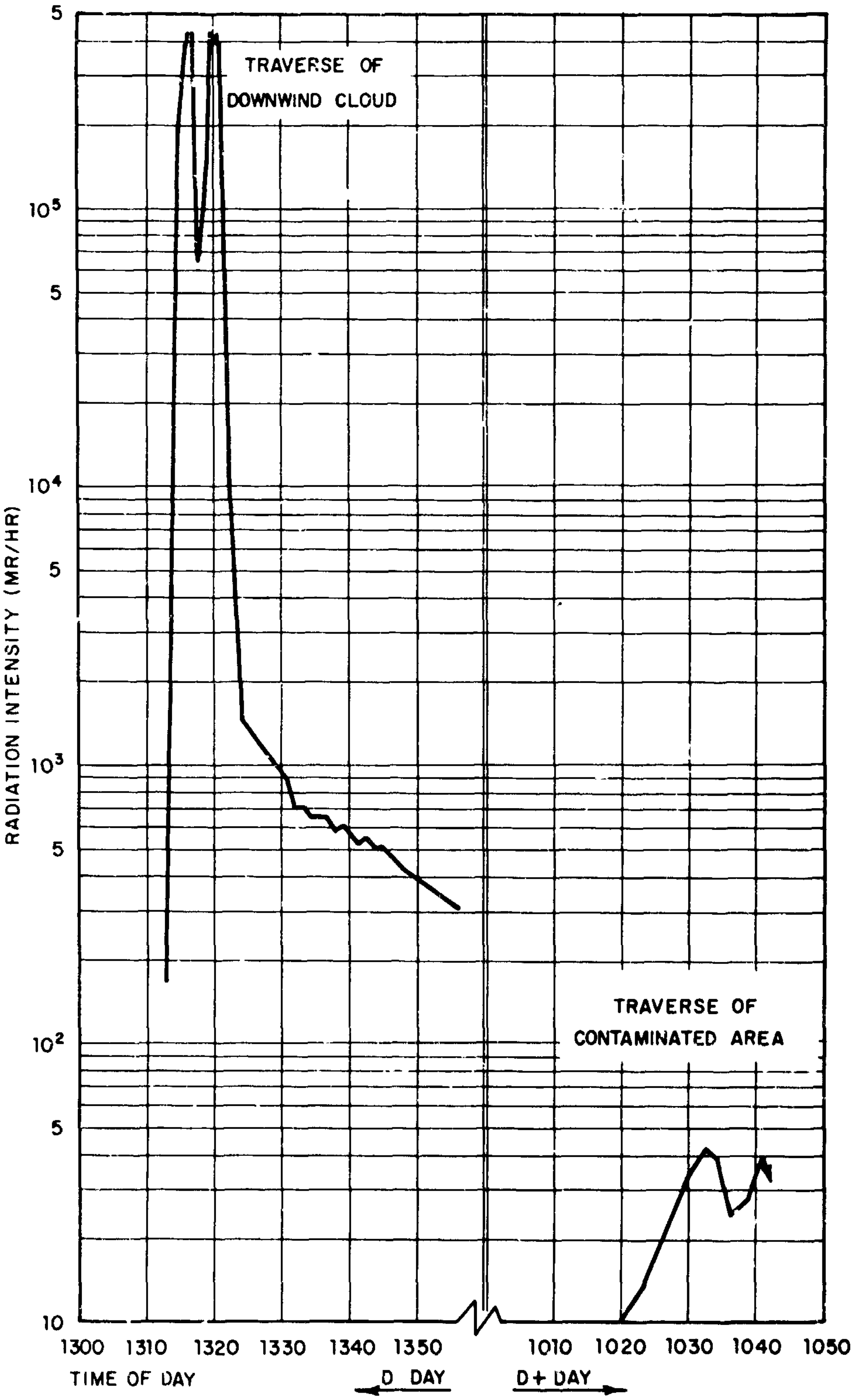


Fig. 4.1 — YAG-39 kingpost radiation log.

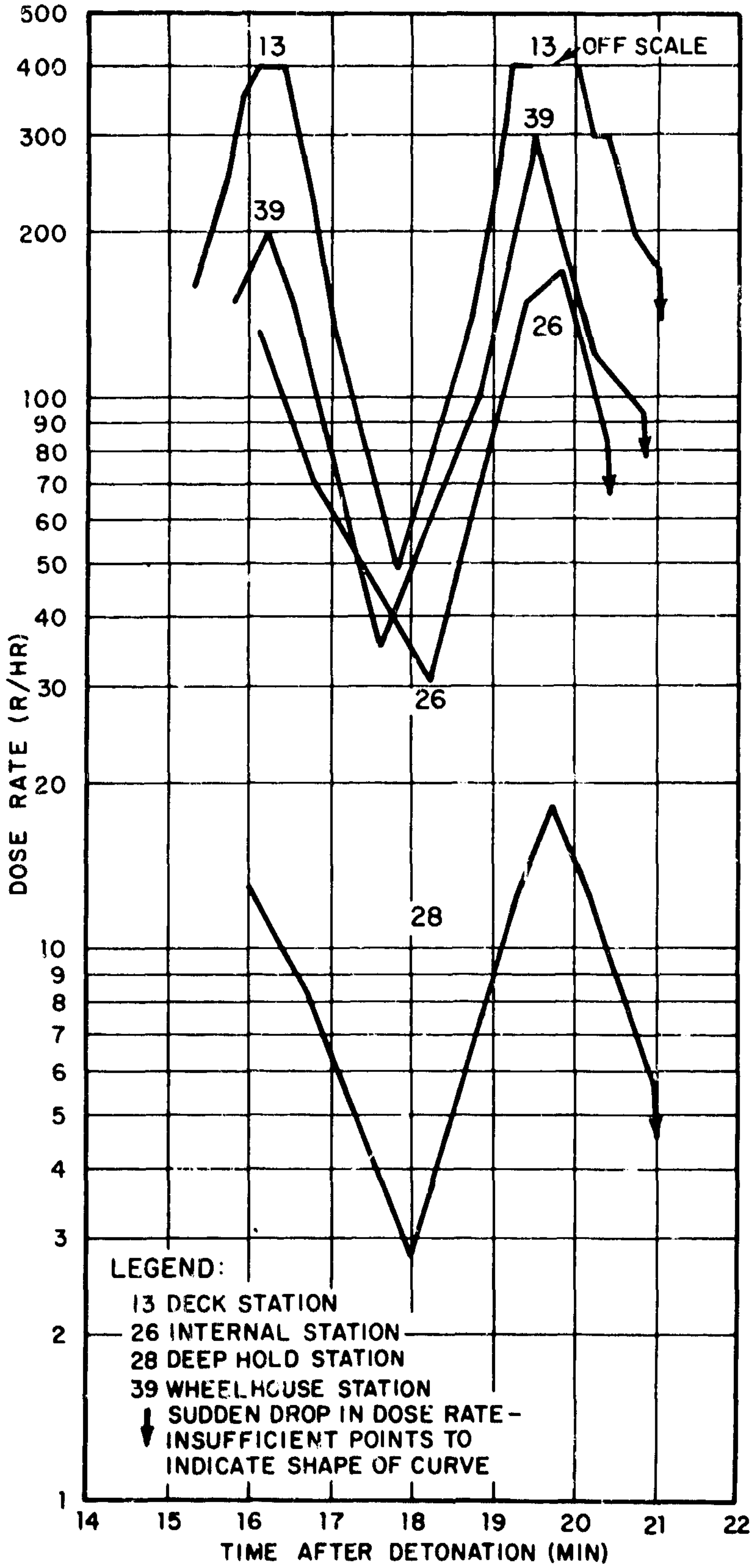
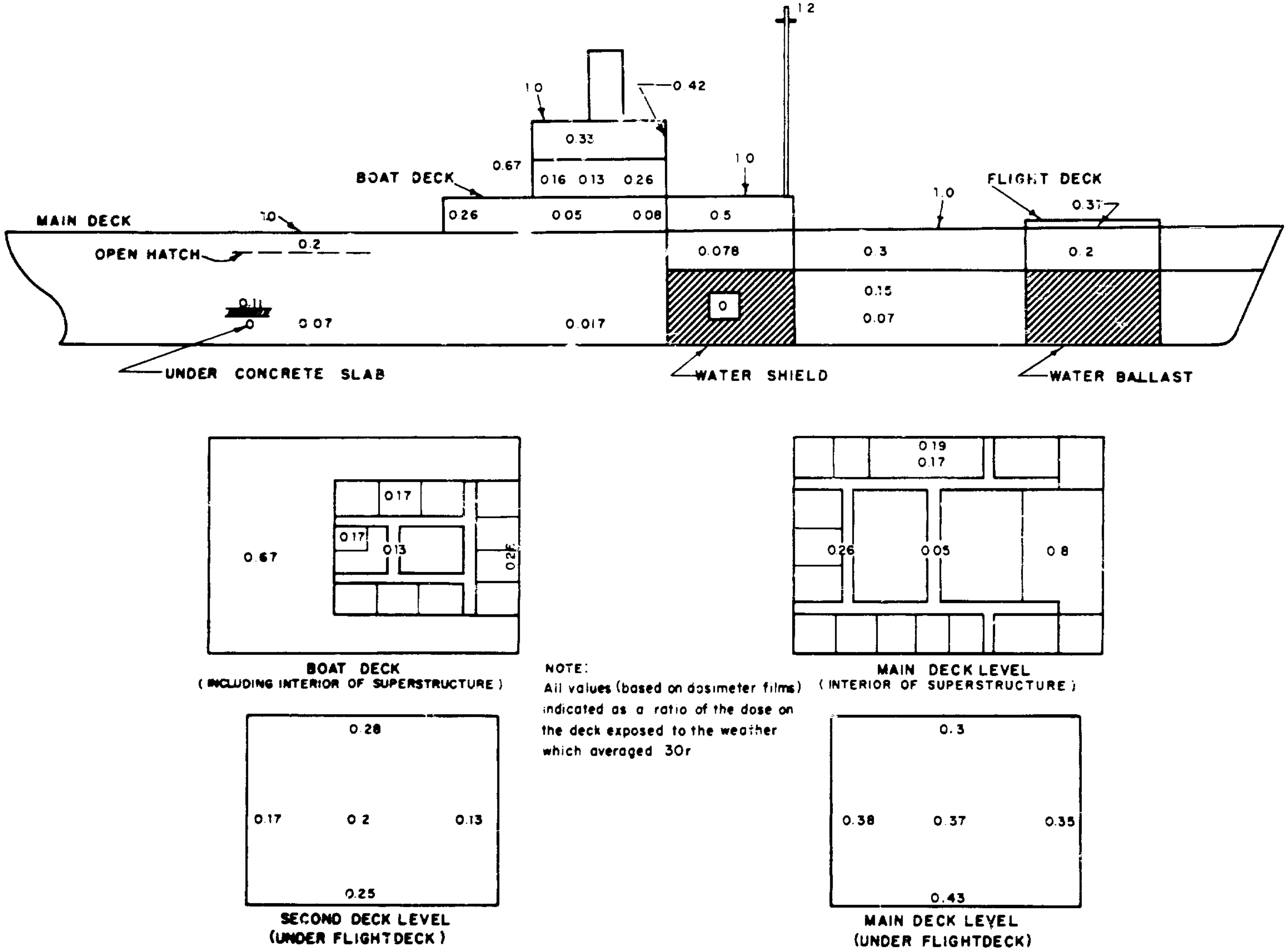


Fig. 4.2—GITR data during traverse of downwind cloud, YAG-39.



NOTE:
All values (based on dosimeter films) indicated as a ratio of the dose on the deck exposed to the weather which averaged 30r

Fig. 4.3—Relative dose distribution throughout YAG-39.

The relatively unshielded lower hold areas received a total dose of 2 r at the center line and 1 r at the extreme port and starboard hulls (below the waterline).

As indicated in Sec. 4.3.2, about 99 per cent of the dose was accumulated during the traverse of the cloud, i.e., before H+22 min.

(b) YAG-40 Data. YAG-40 avoided the cloud and made numerous traverses of the contaminated area on D-day and D+1 day (Fig. 2.1). The dosage-rate readings for the keel and kingpost GITR stations are shown in Fig. 4.4. The dosage accumulated during each pass is shown in Table 4.3. About 85 per cent of the dose was accumulated during the first pass.

Table 4.3 — ACCUMULATED DOSE AND AVERAGE DOSE RATE AT KEEL STATION, YAG-40

Pass	Time of entry to the area	Time after event	Dose accumulated during pass, mr	Time in area, min	Average dose rate, mr/hr
1	D-day, 1351	0:51	3000	25	7200
4	D-day, 1745	4:45	400	23.5	1020
5	D+1 day, 0921	20:21	25.2	28.5	53
6	D+1 day, 1028	21:28	14.4	25.3	35
7	D+1 day, 1118	22:18	17.1	28.8	36
8	D+1 day, 1203	23:03	4.5	20.6	13
9	D+1 day, 1435	25:35	5.4	13	25
10	D+1 day, 1503	26:03	8.1	18	27
11	D+1 day, 1537	26:37	6.3	9.2	41
12	D+1 day, 1610	27:10	21.6	48.5	27

Comparative dose rates in the various parts of the ship during the initial traverse of the contaminated area are shown in Figs. 4.5 and 4.6. On the ship the stations above the waterline (Fig. 4.7) that presumably "saw" primarily a large planar area of contaminated water had similar time vs relative intensity relations. This was true also for the below-waterline stations that saw essentially only two rectangular planes of contaminated water along the hull of the ship. However, the characteristic curves for the two conditions varied somewhat, indicating the relative influence of the various parts of the environment on the dosage rate.

The relative dosage accumulated on the ship during the first 24 hr after detonation is shown in Fig. 4.5. The deck dose, which averaged 1.6 r, ranged from 1.1 to 1.7 r. A station between the evaporator and condenser in the engine room received almost as much as the average deck dose. A dosimetry film in contact with the condenser pump received 3.4 r, about twice the deck dose. However, the dose recorded in the firing aisle between the boilers was essentially background. The radiation level near the condenser and evaporator never exceeded 2 r/hr (Fig. 4.6) but was somewhat persistent, being about 50 mr/hr at H+11 hr. This decrease approximates the radioactivity decay rate, indicating very little elution from the interior surfaces of the units.

As was true on YAG-39, the exposed weatherside deck dosages were higher than those in interior locations. The dose was reduced (from the average deck readings) at stations immediately below the weather deck by about a factor of 3. The reduction factors for stations below the waterline were higher than on YAG-39 but varied according to geometry.

4.5 WASHDOWN STUDIES

The objective of the washdown studies was to evaluate the possible radiological effects associated with operation of a washdown system during the traverse of a contaminated sea area. Specifically, it was desired to know the extent of additional radiation dosage and the amount of residual contamination resulting from the delivery of contaminated sea water by the

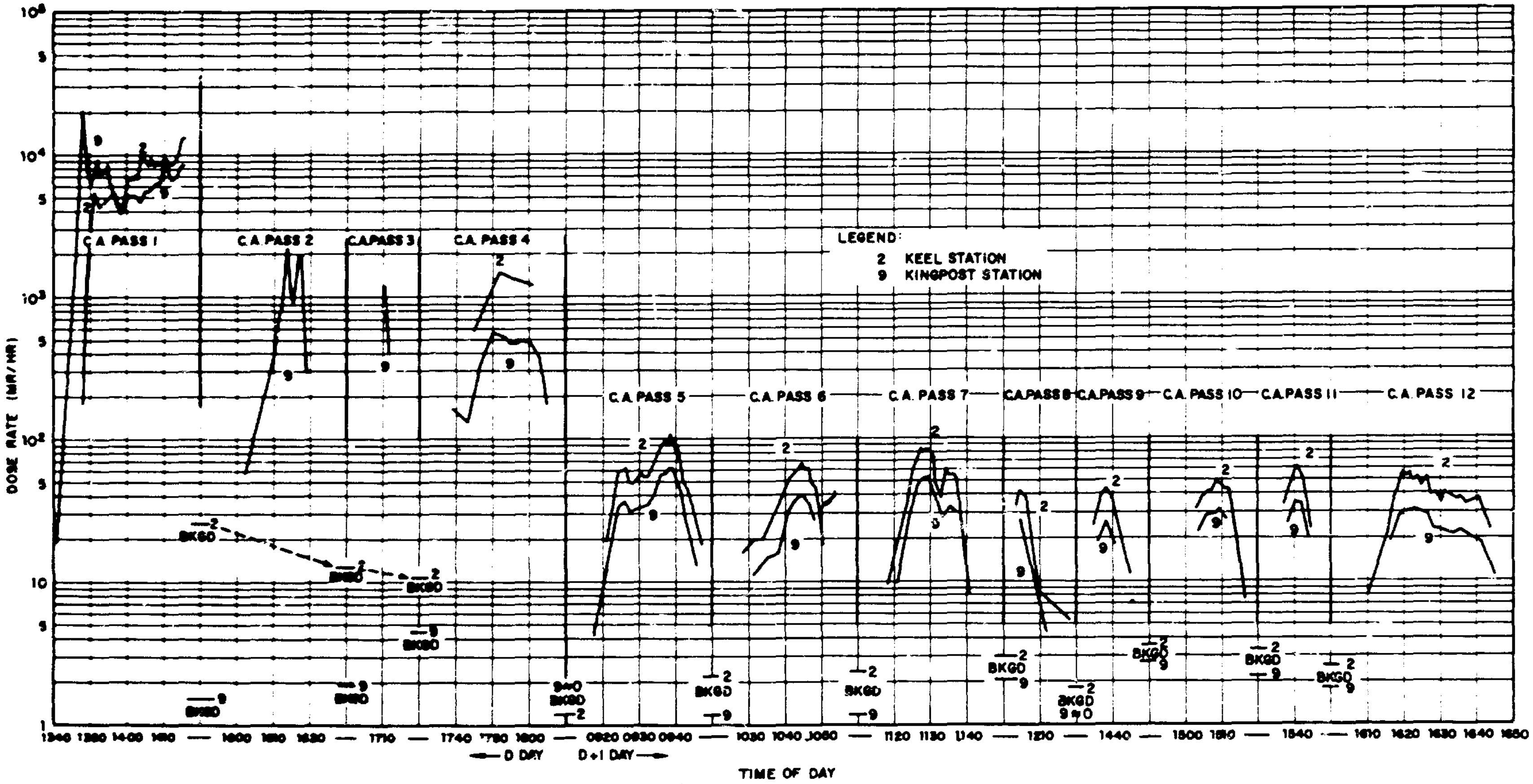
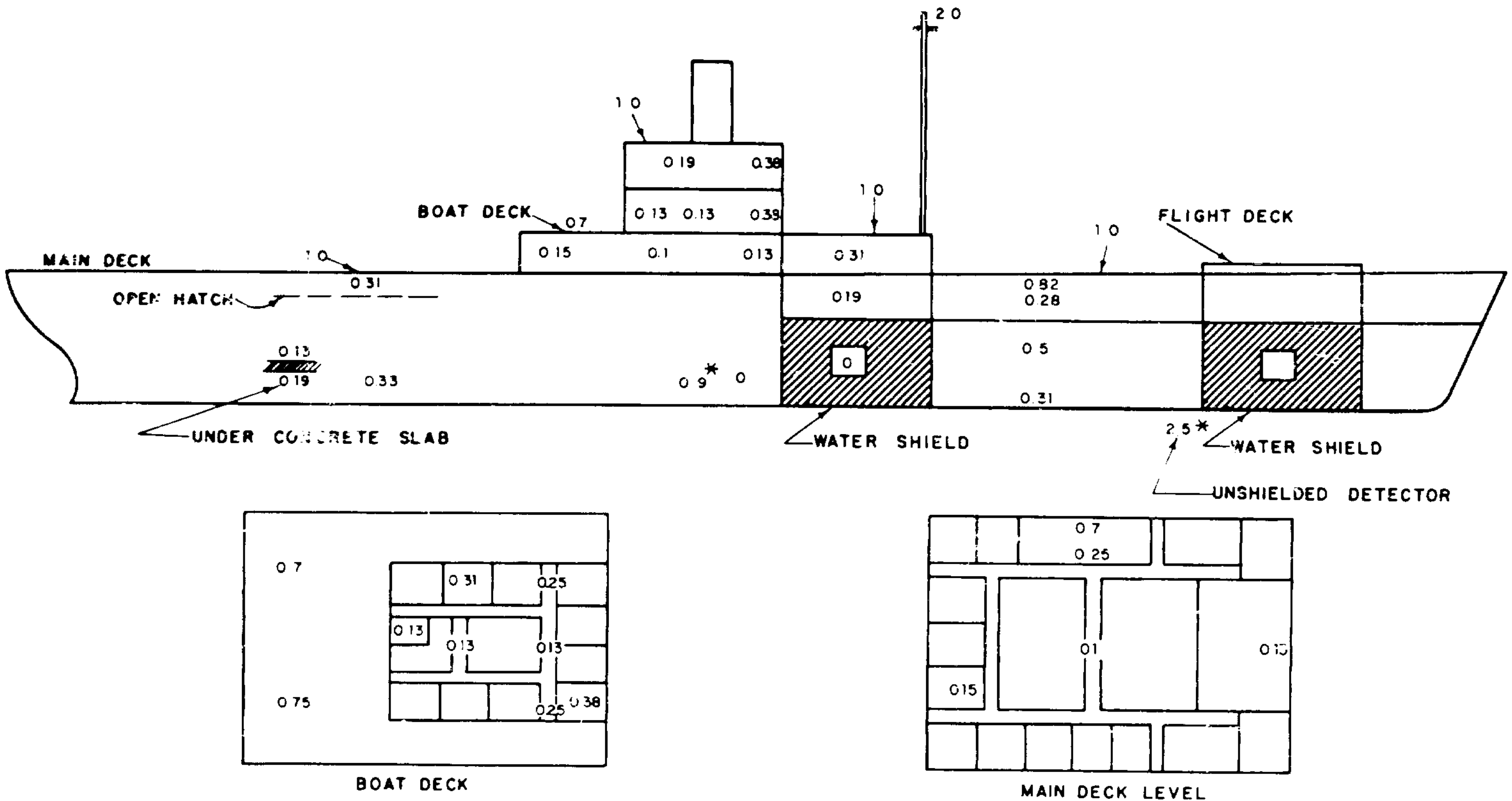


Fig. 4.4—YAG-40 radiation log during traverses of the contaminated area.



NOTE All values (based on dosimeter film) indicated as a ratio of the dose on the deck exposed to the weather which averaged 1.6 r

The lower hold deck and the hull bottom is seperated by 3 1/2 ft of fuel

*GITR Data

Fig. 4.5—Relative dose distribution throughout YAG-40.

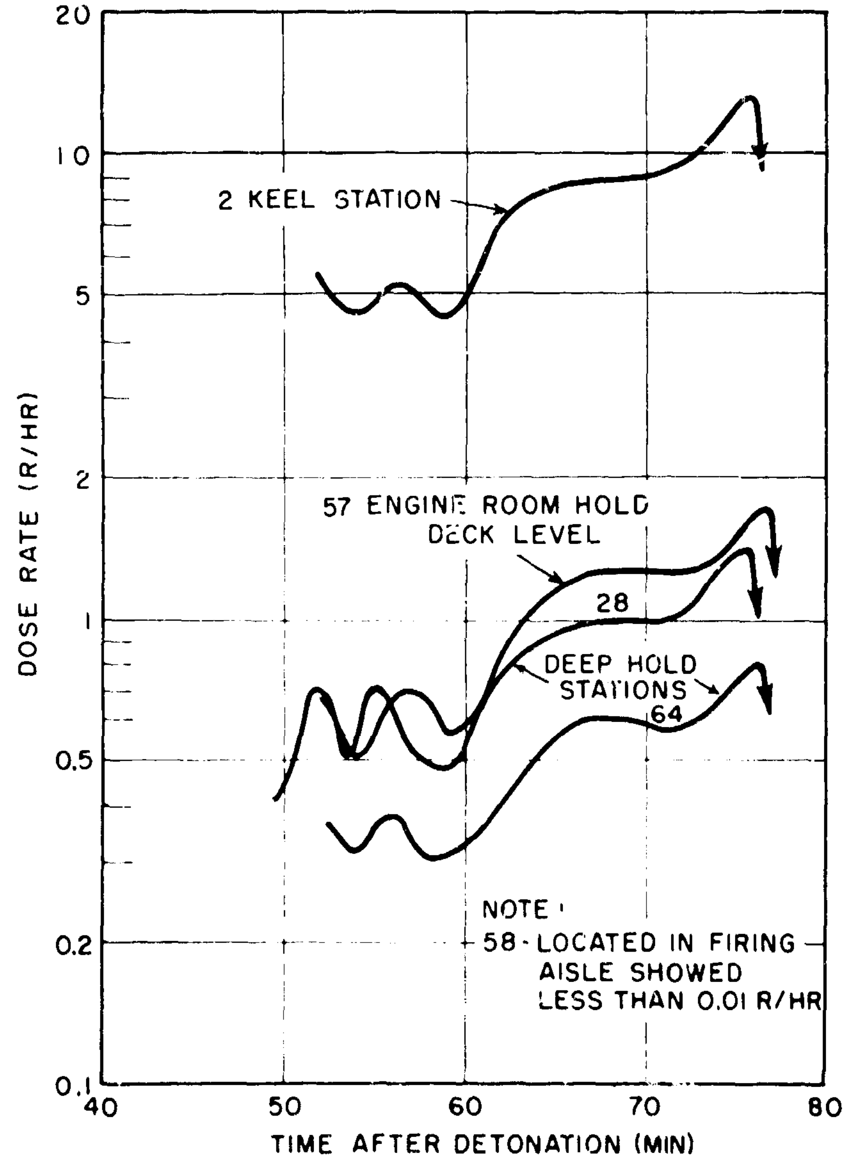


Fig. 4.6—YAG-40 below waterline, GITR data, Pass 1.

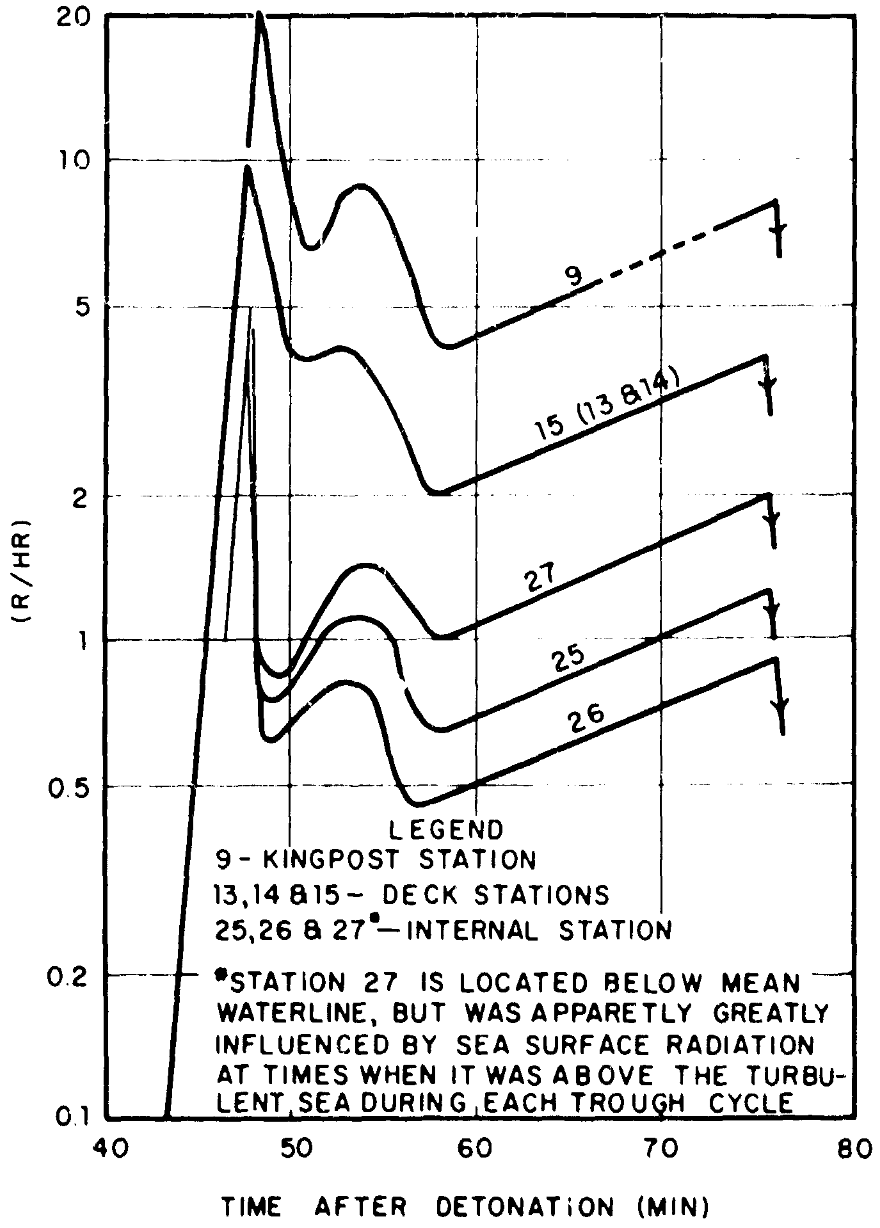


Fig. 4.7—YAG-40 above waterline, GITR data, Pass 1.

washdown system. The available data regarding the washdown effectiveness for fall-out were also to be studied.

4.5.1 Experimental Plan

YAG-39 with washdown and YAG-40 without washdown, operating simultaneously in the contaminated water area, provided comparative data for the first portion of the objective.

The interception of the cloud and fall-out area by YAG-39 provided data for the second part of the objective.

4.5.2 Results and Discussion

(a) Traverse of Contaminated Water Area. A previous estimate[4] indicated that during operation in contaminated water the deck dosage rate would increase by about 10 per cent. During the traverse of the contaminated area on D+1 day, the ships could not be in convoy, and therefore no direct comparison of dose on YAG-39 with that on YAG-40 could be made.

The variable concentration of the contaminated water (see Passes 5 and 6, Fig. 4.4) precluded the possibility of an indirect comparison based upon ships being in the same location. Actually, during traverses of the area at about the same times, the dose rate on the deck of YAG-40 was about equal to or higher than that on YAG-39. This can be attributed to the ship being in areas of higher concentration of radioactive material.

Table 4.4 gives the dose rates of Stations 9, 13, and 32 on YAG-39 before, during, and after the traverse of the contaminated sea areas, as well as the net increase in radiation dose rate. Contaminated water was dispensed by the washdown system, and Stations 13 and 32 were continually showered with this water. An examination of the dose rates at this time showed that Station 9, located above the washdown spray, was irradiated at more than twice the deck-station rates. This ratio during washdown was similar to the (nonwashdown) ratio aboard YAG-40. Thus it appears that the major component of the radiation received by the washdown ship was from the contaminated sea and that the amount contributed by the washdown system was relatively small.

Table 4.4—RADIATION DOSE RATES ABOARD YAG-39, D+1 DAY

Station	Before entry (0900), mr/hr	Peak intensity during traverse, mr/hr	After exit (1130), mr/hr	Net increase in contamination of pass, mr/hr
9 (kingpost)	0.58	42	0.47	0
13 (deck)	0.11	21	0.53	0.44
32 (deck)	0.11	16.5	0.71	0.62

Additional information was found during the traverse when the washdown system was turned off at 1030 and reactivated at 1040. No change in the curve, Fig. 4.1, at these times could be attributed to the washdown-introduced radiation-dose change.

The washdown water was contaminated, however, and left residual contamination upon the weather surfaces as indicated in Table 4.4.

These data indicated that the radiation level due to the residual contamination was about 2 to 4 per cent of the peak readings on deck during the traverse of the area. Using this figure, it may be calculated that, if YAG-40 had operated a washdown system during its first traverse on D-day, the residual radiation on its weather decks would have amounted to about 100 to 200 mr/hr. This would be reduced by decay to about 2 mr/hr at H+24 hr.

(b) Envelopment by the Cloud. The data required for the determination of washdown effectiveness during and subsequent to encountering the cloud of airborne weapons debris downwind from the detonation were limited. Washdown effectiveness based on dose rate can be

estimated by comparing an unwashed area (the kingpost platform) with washed areas (main weather deck). The data available were:

Kingpost platform reading at H + 1 hr (fixed gamma station)	280 mr/hr
Kingpost platform reading at H + 24 hr (survey reading), 1 mr/hr — calculated for H + 1 hr	310 mr/hr
Average deck readings taken between H + $1^2/_3$ to H + 2 hr and corrected for H + 1 hr	9 mr/hr

The data obtained at Operation Castle for YAG-39 after Shot 5 (and at H + 12 hr) indicates that the washdown effectiveness based on a comparison of the dose rate on the unwashed kingpost to that of the washed deck was 96.7 per cent. At the same time the washdown effectiveness based on a comparison of dose rates on YAG-39 with those on YAG-40 was essentially the same (96.3 per cent). This fact would tend to indicate that a washdown effectiveness determination based on a comparison of deck-to-kingpost dose rate would be valid. Nevertheless, Operation Castle data also indicate that on YAG-40 on Shots 4 and 5 the ratio of the dose rate on the unwashed kingpost to the mean dose rate on the unwashed main deck forward was about 1.3 and 0.7, respectively. In other words, the reading at the kingpost was indicative of the main-deck dose rate within that range. If these values are assumed to be limits applicable to this situation, then the washdown effectiveness on YAG-39 at Wigwam was between 95 and 98 per cent, at 1 hr, based on a dose-rate comparison of weather deck and kingpost.

Of more significance is the washdown effectiveness as determined by accumulated radiation dosage. Based upon film-badge readings, survey data, and gamma intensity-time records, Table 4.5 indicates the approximate radiation dosage accumulated during various periods and the over-all washdown effectiveness achieved during the period.

Table 4.5 — DOSE ACCUMULATED DURING VARIOUS EXPOSURE PERIODS ON YAG-39

	Kingpost (Sta. 9)		Main deck forward (Sta. 13)		Apparent washdown effectiveness during period, %
Exposure period	mr	%	mr	%	
13 to 22 min	34,000	97.0	29,700	99.0	12.5
22 min to 1 hr	540	1.5	260	0.9	52
1 to 10 hr	410	1.2	12	0.1	97
10 to 20 hr	60	0.2	2	0.1	97
Approximate total to 20 hr	35,000	99.9	30,000	100.1	14

The maximum washdown effectiveness was attained after 1 hr; however, the dominating influence of what is undoubtedly the so-called "transit dose" from the cloud significantly reduces the over-all effectiveness of the washdown to 14 per cent during the period of interest.

4.6 SHIELDING STUDIES

Shielding studies were conducted to supply additional data and information to that obtained at Operation Castle for evaluating the effectiveness of naval ship structures as shielding against the radiations from the fall-out, the transient cloud, and the contaminated sea area.

4.6.1 Experimental Plan

Radiation-attenuation data were obtained from gamma-detecting stations mounted on the weather deck of YAG-39 which were respectively shielded by enclosure within steel cylinders of $^1/_8$, $^1/_4$, $^1/_2$, 1, 2, and 4 in. in wall thickness.

Four unshielded gamma stations located at various heights above the hold bottom were installed in the Hold 2 section of both YAG-39 and YAG-40 to provide structural and space shielding data. During each phase of the ship's operation in the contaminated area, the radiation received by the gamma detectors at each station was recorded and compared with the data from an unshielded detector station on the weather deck above them.

4.6.2 Results and Discussion

Figure 4.8 compares the attenuation curve of steel compiled from the YAG-39 Wigwam data with two other attenuation curves. The curves are the Wigwam curve, 18 min after detonation; the Castle curve, 2 hr after detonation; and the Castle curve, 50 hr after detonation. These curves were obtained by normalizing the dose rates measured inside closed steel cylinders and plotting the results as a function of cylinder thickness. The slope of the attenuation curve is determined by the energy spectrum, the nature and geometry of the shield, and the geometry of radiological environment. For the case of identical shields and environmental geometries, changes of slope can be attributed to changes in the energy spectrum—in general, the flatter the slope the higher the mean energy. Castle data showed this trend.

If it is assumed that the environmental geometries are equivalent and that the early time vs energy characteristics for Wigwam and Castle data are equal,* then the curve obtained in this test confirms the trend of observing continually higher effective energies at earlier times.

The data from the cylindrical steel shields are limited since significant radiation fields were encountered for only a very short time.

The inherent shielding (and geometry) characteristics of the ships were obtained by comparing the unshielded detector array in Hold 2 of the ships (Fig. 4.9). The shielding factors so derived are shown in Table 4.6; Castle data are also shown. Since shielding factors based upon dose were not derived at Castle, dose-rate data at an arbitrarily chosen 3 hr are included.

On YAG-40, at Operation Wigwam, Station 27 received a greater dose than Station 28; Station 25 received a greater dose than Station 26. The first thought is that the concentration was greater at the water surface than immediately below the surface, but this is not necessarily the situation. Figure 4.9 shows that Stations 26 and 28 were geometrically better shielded than Stations 25 and 27, respectively. The intervention of the second deck to all radiation from the sea impinging on Station 26 is noted. It should also be noted that, when the sea is low on the hull, Station 27 receives radiation from the sea surface.

The Castle data varied with the different events, and YAG-39 tended to indicate more effective shielding. The resemblance of the shielding factors from the fall-out at Castle to those from the transient cloud at Wigwam is discernible, whereas the shielding factors due to the contaminated water at Wigwam differ from the other cases.

4.7 HULL PAINT STUDIES

The objectives of the hull paint studies were (1) to determine whether the hull of the ship in passing through water contaminated by an underwater nuclear detonation would collect contamination to an extent to be of tactical consequence and (2) to determine whether there was an appreciable difference in the contaminability and decontaminability characteristics of various ship-bottom paints.

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*At early times it is expected that attenuation curves determined at Wigwam would be identical with those that might have been obtained at Castle. During the first few hours the neptunium would not have had a chance to build up, and the fission-product energy spectrum should predominate.

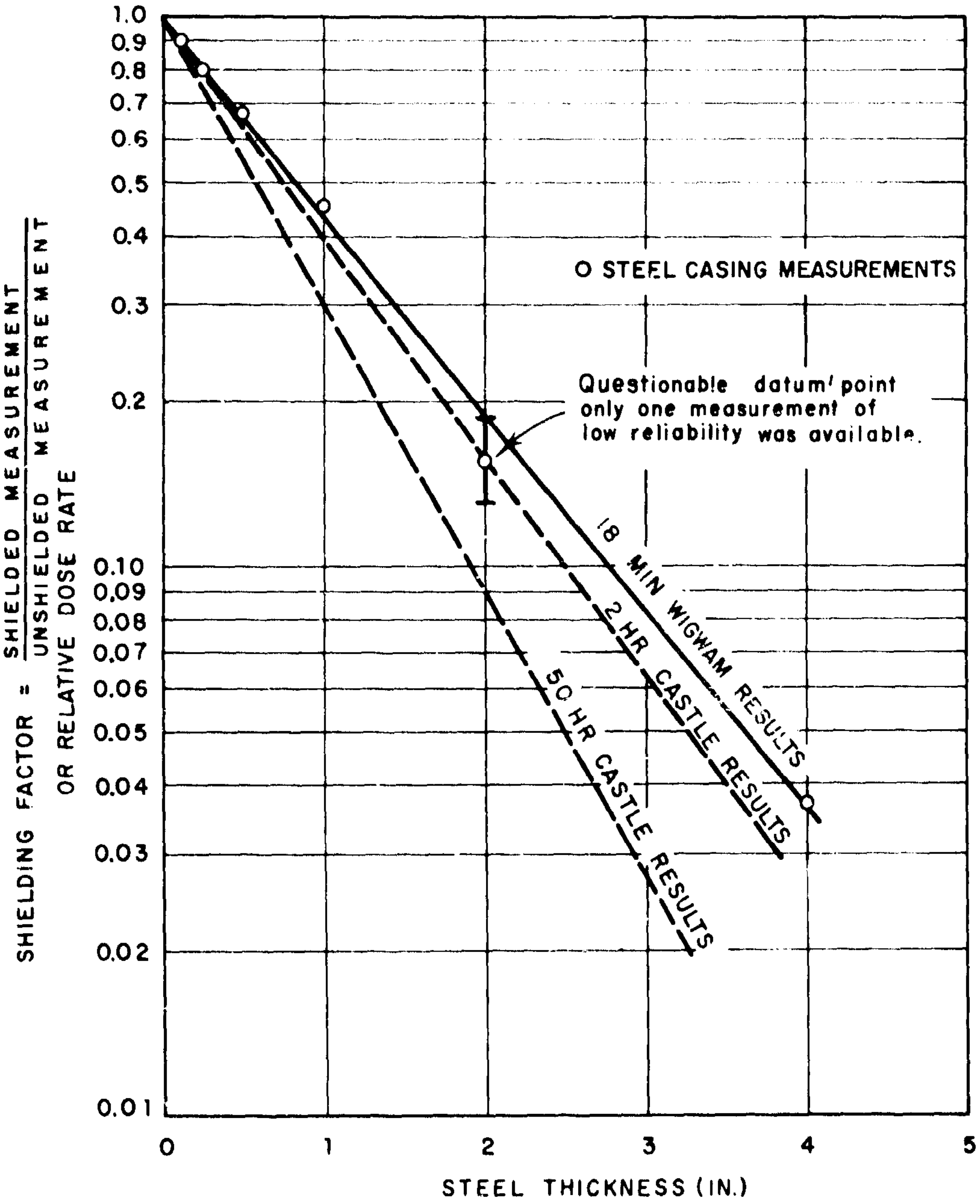
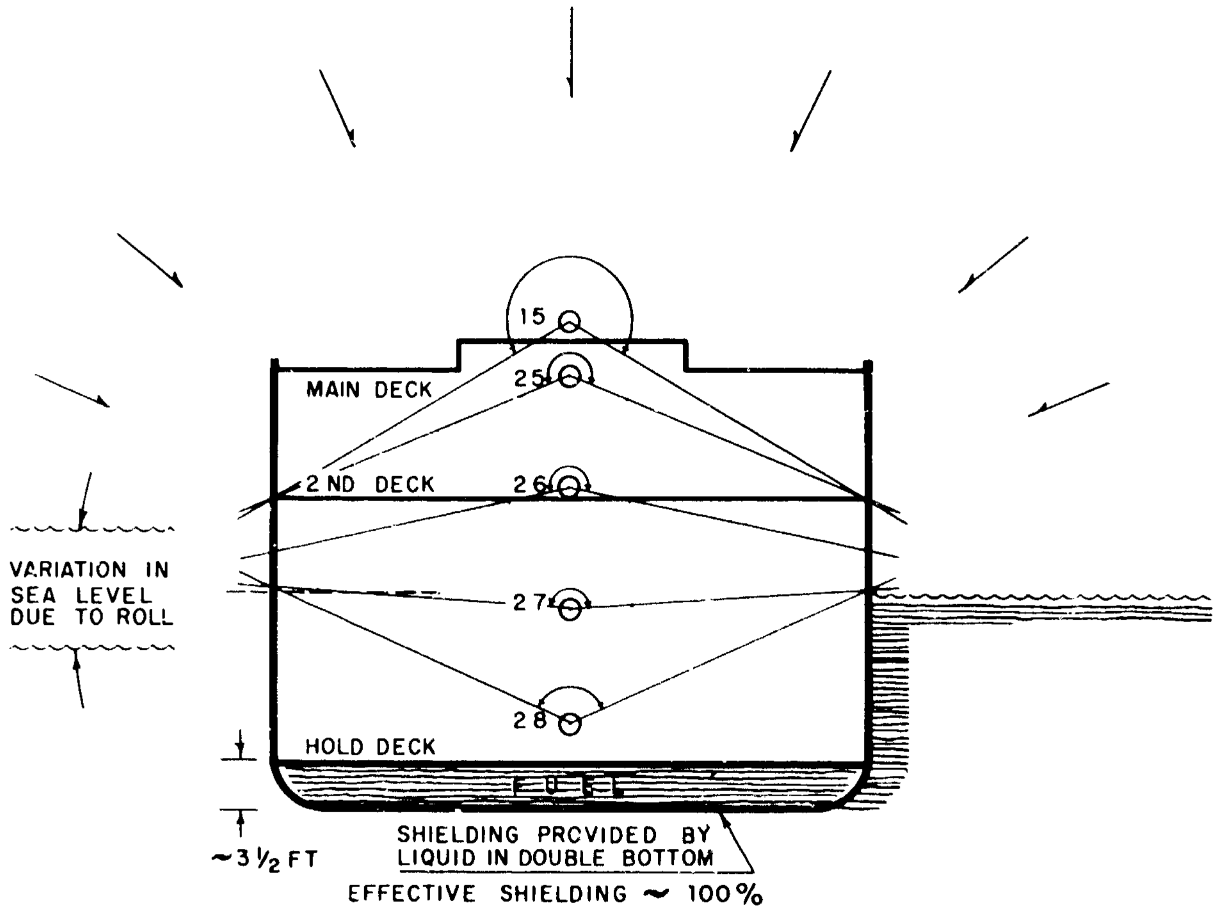
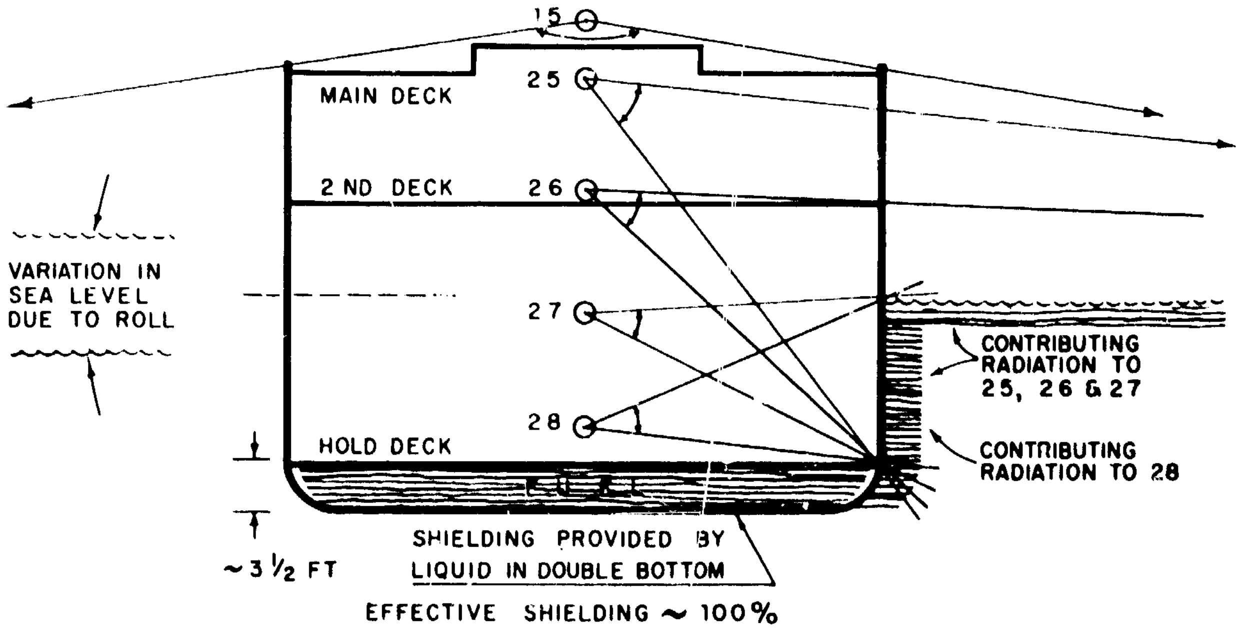


Fig. 4.8—YAG-39 shielding factors for closed steel cylinders.



YAG 39 - TRAVERSE OF TRANSIENT CLOUD



YAG 40 - TRAVERSE OF CONTAMINATED WATER

Fig. 4.9—Assumed geometry of ships, detectors, and environments.

Table 4.6 — SHIP SHIELDING FACTOR* COMPARISON

Radiological environment	Wigwam transient cloud	Wigwam contaminated water area		Castle fall-out ship contamination	
Ship	YAG-39 with washdown	YAG-40 without washdown		YAG-39 with washdown	YAG-40 without washdown
Measurement method	Dose to H + 20 hr by film	Dose to H + 24 hr by film	Dose (H + 1 to H + $1\frac{3}{4}$ hr) by GITR	Dose rate at H + 3 hr by GITR†	Dose rate at H + 3 hr by GITR†
Station	Shielding factor				
15	1	1	1	1	1
25	0.28	0.58	0.32	0.14/0.32	0.18/0.20
26	0.30	0.32	0.23	0.13/0.25	0.07/0.25
27	0.14	0.56	0.50	0.06/0.12	0.06/0.08
28	0.10	0.36	0.33	0.04/0.10	0.05/0.06

* Shielding factor = $\frac{\text{measurement at station}}{\text{measurement on weatherdeck (Station 15)}}$.

† Minimum/maximum readings from data from Shots 2, 4, and 5 at H + 13 hr.

4.7.1 Procedures

The paint systems used in this evaluation were chosen by the Head, Mare Island Naval Shipyard (MINS) Paint Laboratory. They were (1) formula 15HP, a hot plastic paint which is used widely in protecting the underwater surfaces of naval vessels; (2) formula 15HP emulsion (MINS experimental), a new cold-water emulsion paint which has shown promise in overcoming some of the application difficulties of 15HP and certain improvements on operational characteristics; (3) formula 105, a solvent antifouling paint, which is used where hot plastic application facilities are unavailable; and (4) formula 121, a vinyl base paint, which is used on submarine hulls.

YAG-39 was used to compare freshly painted 15HP with 15HP that had been on the hull for 18 months. All four paints (freshly applied) were compared on the hull of YAG-40. The painting layout for YAG-40 is given in Fig. 4.10. The physical appearance of the four paints immediately after painting is shown in Fig. 4.11.

The ideal experimental plan for this study would have required each ship to make only one pass through the contaminated area at an early time after detonation. However, it was operationally necessary for YAG-40 to make two passes on D-day and several more on D+1 day. YAG-39 traversed the area on D+1 day only. The levels of radioactivity on D+1 day were too low to interpret.

Data were obtained from GITR's, portable gamma rate meters, and dosimeter film packs. All measurements were made on the interior surfaces of the hull and in the spaces of Holds 2 and 4. GITR data from Stations 27 and 28 (Fig. 4.9) indicated the radiation intensity from the contaminated water during traverse of the area and that from the residual contamination adhering to the hull subsequent to the traverse.

The portable gamma rate meters, type AN/PDR-T1B,* were used to differentiate the contaminability-decontaminability characteristics of the different paints. Approximately 200 survey locations were established on the interior surface of the hull plating. These locations were below the waterline and were spaced about 5 ft apart. There were 112 survey locations in Hold 2 and 93 in Hold 4.

Dosimeter film packs, Du Pont types 552 and 558, provided (1) information regarding the integrated gamma-radiation dose accumulated during the test period and (2) a cross check on the other data. Films were also used before the test to determine the background radiation intensity. All film packs were attached to the interior hull surfaces at suitable survey locations; 28 were located in Hold 2, and 12 were in Hold 4.

4.7.2 Results and Discussion

(a) Contaminability-Decontaminability Characteristics. The data used in this section were obtained from the recording gamma detector at Station 27, which was located just below the draft line in the center of Hold 2. This station received radiation from the four paint test areas on the hull at Hold 2.

Figure 4.12 shows radiation-dosage rate vs time after detonation and Fig. 4.13 and Table 4.7 show the accumulated radiation dosage vs time after detonation.

The average dose rate during the first pass was about 1100 mr hr. A very short time after the ship left the area the dosage rate had dropped to about 60 mr hr or about $5\frac{1}{2}$ per cent of the intensity during the traverse. This initial decrease was probably due not only to escaping the main body of contaminated water but also to the gradual replacement of the contaminated "laminar flow" layer along the hull by clean water. The radiation intensity continued to decrease more rapidly than the natural decay rate, thereby indicating continued elution by clean sea water. The combined decay-elution vs time curve (Fig. 4.12) appeared to have an exponential "decay" exponent of about −1.8.

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*It was assumed that, if the level of the radioactivity was such that a T1B was not sensitive enough to accurately measure it, the hull contamination problem would be considered insignificant.

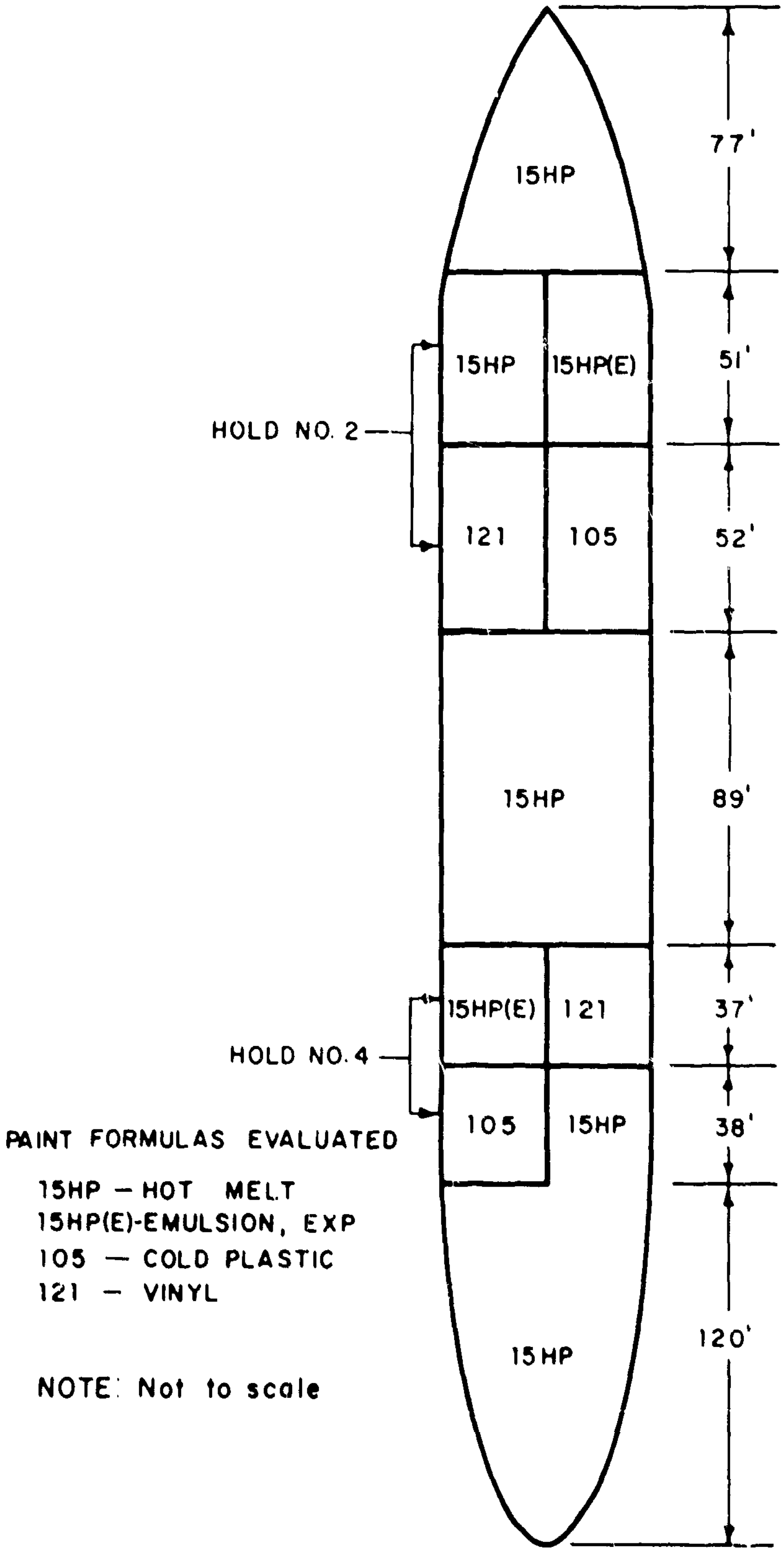

Fig. 4.10—Plan view of hull painting scheme for YAG-40.

Formula 15HP hot melt

Formula 15HP emulsion (MINS experimental)

Formula 105 cold plastic

Formula 121 vinyl

Fig. 4.11 — Appearance of hull paints tested on YAG-40 (actual-size photographs).

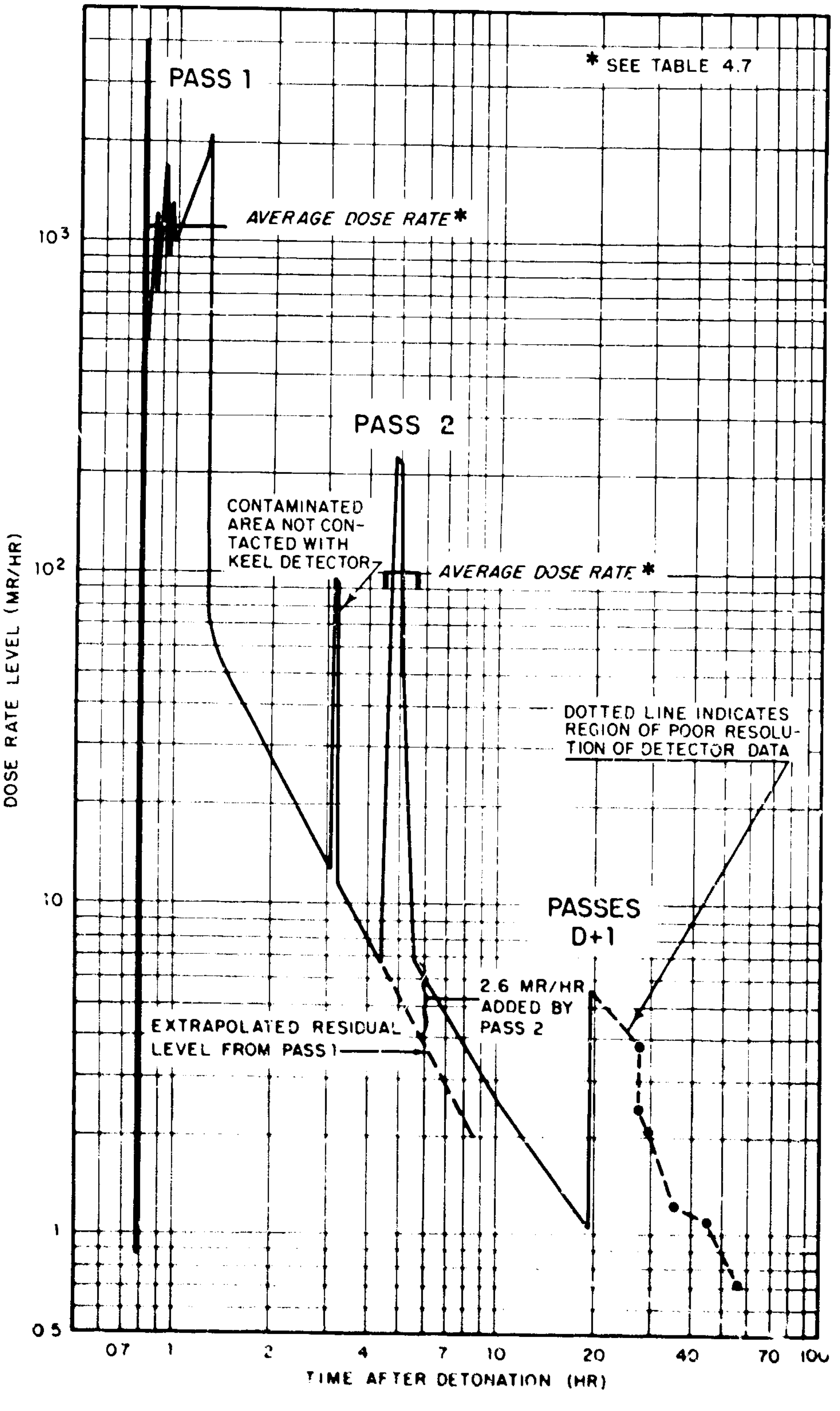

Fig. 4.12—Dose rate at Station 27, in Hold 2, of YAG-40.

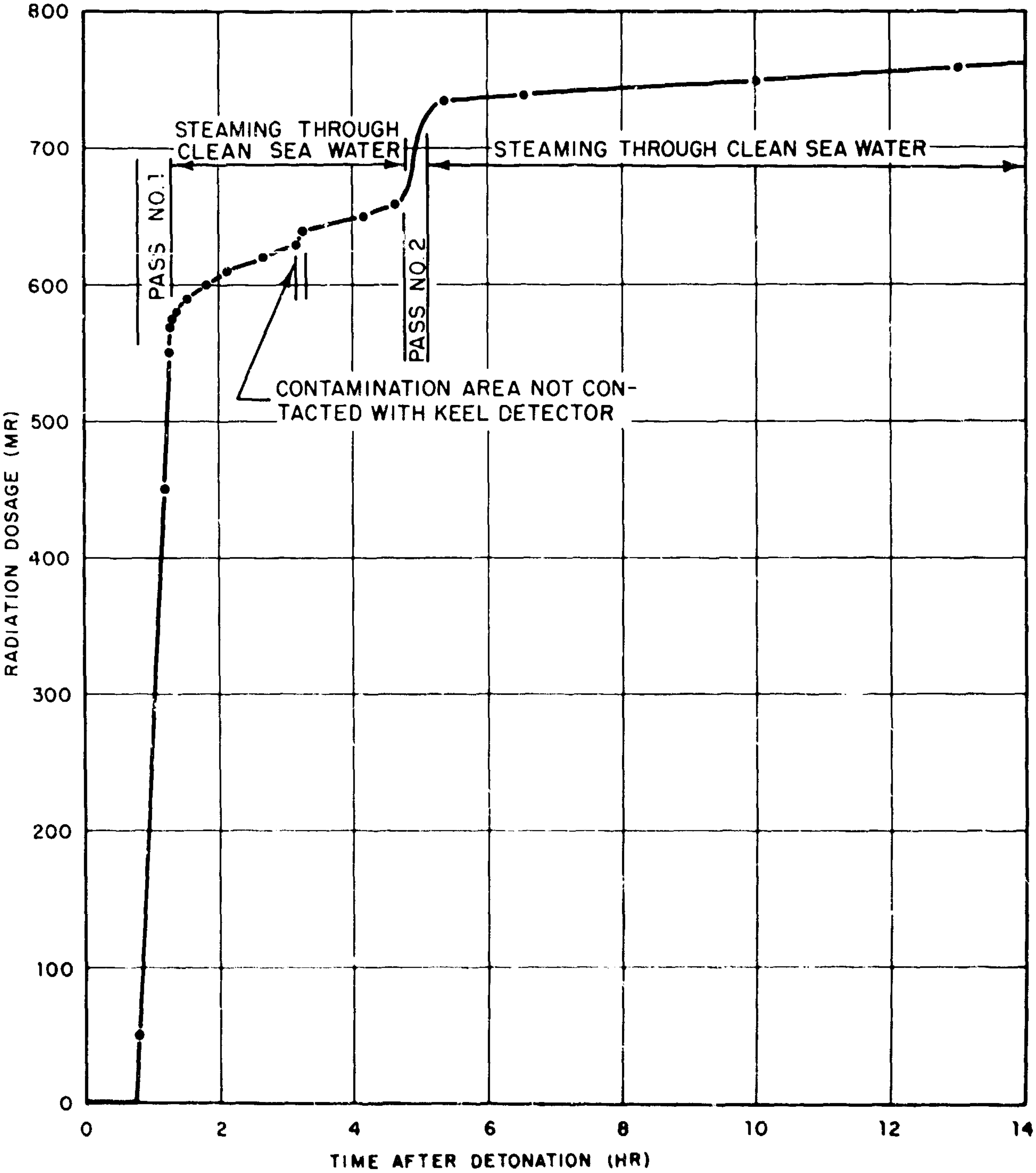

Fig. 4.13—Accumulated radiation dosage at Station 27, in Hold 2, of YAG-40.

Table 4.7—DOSAGE ACCUMULATED IN YAG-40 HOLD 2 ON D-DAY

Event	Time: Start, hr after H-hour	Time: End, hr after H-hour	Time: Elapsed, hr	Dose accumulated: mr	Dose accumulated: %	Average dose rate, mr/hr
First pass through contaminated water area	0.77	1.28	0.51	575	76	1130
Operating in clean water area	1.28	4.60	3.32	65	9	
Observed "shine" from contaminated area	3.14	3.25	0.11	15	2	
Second pass through contaminated water area	4.60	5.40	0.80	81	11	100
Operating in clean water area	5.40	10.00	4.60	14	2	
Total				750	100	

The Pass 2 dose rate averaged 100 mr/hr. The residual contaminant added by the pass resulted in about a 2.6 mr/hr increase (Fig. 4.12) or about $2\frac{1}{2}$ per cent of the average intensity during the traverse.

The total dosage accumulated from the residual contamination was only $1\frac{1}{2}$ per cent of the total received during the 10 hr.

Radiation-dosage levels at the time of dry-docking were below 0.2 mr/hr gamma and 0.01 μc/sq cm beta, the most sensitive possible readings of the instruments used. No Rad-Safe precautions for hull work were considered necessary by the San Francisco Naval Shipyard.[5]

The factors that most probably are dominant in determining the amount of residual radioactivity on the hull of a ship passing through a contaminated area are (1) hull paint age and conditions, (2) concentration and chemical state of fission products in the contaminated water, and (3) stay time in the contaminated water. Factors that determine the importance of the dosage due to the residual radioactivity on the hull relative to the dosage due to crossing the contaminated area are those just mentioned and also (4) the age of the fission product. Quantitative information for these factors is not available from this test.

(b) Comparison of Paints. The paint comparison is based on gamma rate data taken at H+9 hr. The surfaces had undergone both contamination and decontamination phases. An independent comparison was made for each of the two test groups because of the apparent difference in the characteristics of the forward and after parts of the ship. The results are shown in Figs. 4.14 and 4.15.

The spread in the data within paint areas of the portside of Hold 2 was the greatest. An "isorad," Fig. 4.16, shows that the irregular distribution of radioactivity on the side of the hull was not entirely random. It appears that a layer, or patch, that was submerged about 10 to 15 ft was struck and spread along the side. When the ship was dry-docked six months after the test, there was no visible evidence of the possible cause of the irregular distribution of contaminant on the hull. An analysis of variance of the Hold 2 data shows that no significance can be attributed to the differences in the residual radioactivity for the paints tested with the 90 per cent confidence interval.

A similar analysis of the data from Hold 4 does show a difference between the paints, and, since there was no such wide spread of the data for the area at Hold 4, it is assumed that enough mixing by the passage of the ship had occurred to eliminate evidence of lamination.

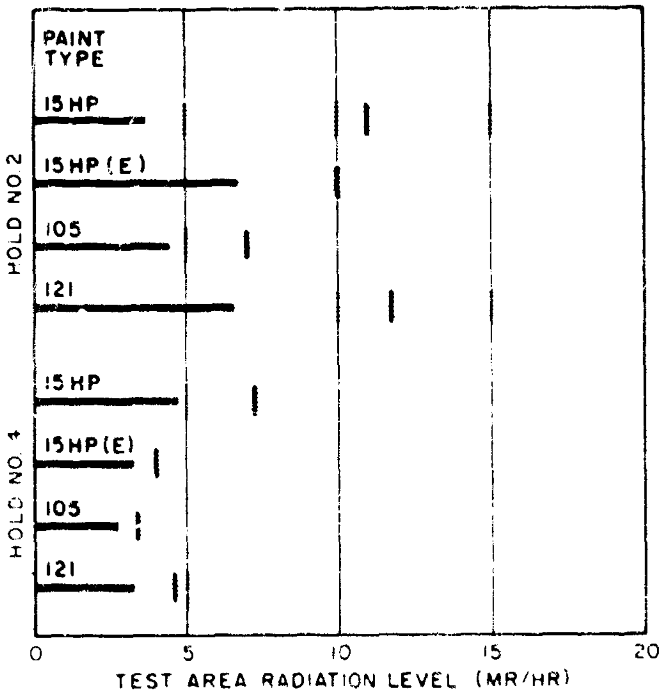

Fig. 4.14—Paints compared by radiation dose rate.

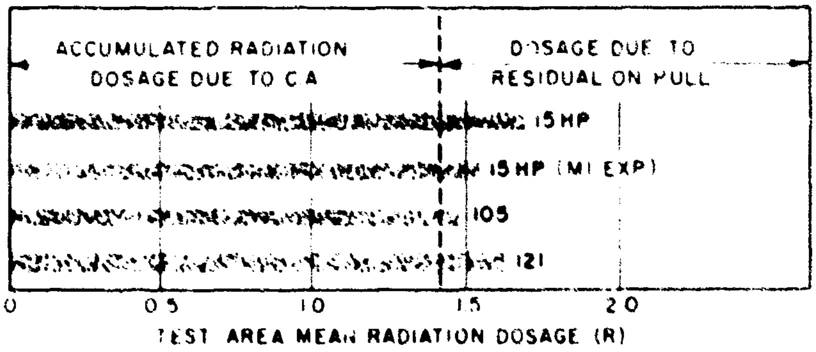

Fig. 4.15—Paints compared by radiation dosage.

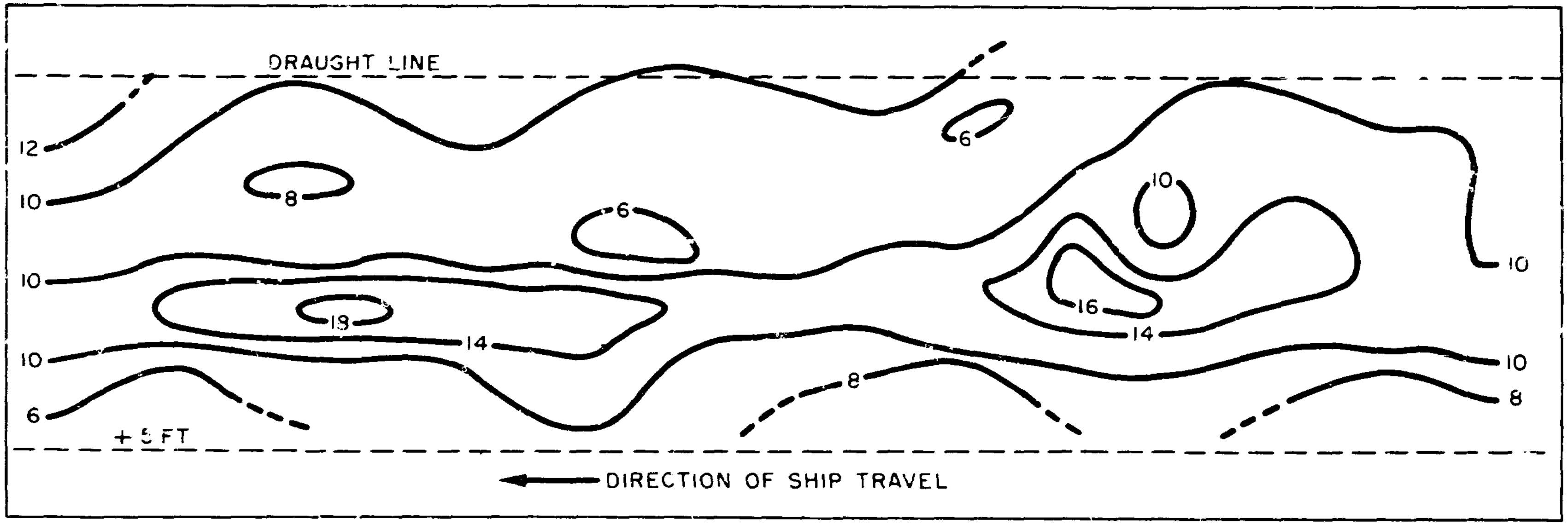

Fig. 4.16—Distribution of contaminant at H + 9 hr, YAG-40, Hold 2, port.

On both the dose rate at H+9 hr and the accumulated dosage comparisons, the 15HP (MINS experimental) and 105 formulas appeared less contaminable (or more decontaminable). The over-all difference in the amount of contamination present (as measured by dose rate) was about a factor of 2. The difference based upon accumulated dosage (including that received during the traverse of the area) was much less.

Comparison with the 18-month-old paint was not accomplished.

4.7.3 Conclusions

For the test conditions encountered, there appeared to be no tactical significance to the residual radioactive contamination on the hull after the ship traversed the radioactively contaminated area, nor was there a radiological safety problem when the ship was dry-docked.

Although there was statistical significance to the reactions of the various paints to the contaminated water, undetermined factors caused variations as great as variations due to paint difference. The mean hull radiation-dosage rate was about 6 per cent of the average contaminated water radiation-dosage rate.

The results indicate that the problem is of such a nature that hull contamination could probably become significant only (1) in dry-docking a freshly contaminated hull under peacetime radiological safety regulations or (2) when, in the event that the ship's crew received a near-lethal dose of radiation in crossing the contaminated water, any additional radiation dosage would cause an increase in the number of casualties.

4.8 REMOVABLE RADIOLOGICAL PROTECTIVE COATINGS

The principal objectives of the work with removable radiological protective coatings (RRPC) were:

1. To determine the removability, contaminability, and decontaminability characteristics of the latest RRPC formulations.
2. To determine the feasibility and effectiveness of removing unprotected standard Navy paint with a chemical paint stripper as a tactical decontamination procedure.
3. To determine the feasibility and effectiveness of a decontamination procedure consisting of a stepwise removal of a strippable protective coating followed by a chemical removal of standard Navy paint.

Objectives 2 and 3 were not accomplished because the radiation intensities on the test areas were not high enough to warrant decontamination.

4.8.1 Experimental Details

Representative weather-surface areas of YAG-39 were coated with RRPC and exposed to the contaminating fall-out from a deep underwater nuclear detonation and to possible contamination from the washdown system as the ship traversed a contaminated water area. The RRPC was removed the same day it was exposed to the contamination.

The most favorable RRPC formulation was applied to the following areas of YAG-39: from the bulkheads aft of the flight deck to the after end of Hatch 2 and extending out to include both the port and starboard gun tubs, decks, bulkheads, and railings; and a strip from the starboard to the port rail along the length of Hatch 5 and including all deck, bulkhead, and railing surfaces.

Because of the poor surface condition of the boat deck, the RRPC was applied at the test site prior to D-day. The payed areas were heavily coated with standard Navy deck gray paint and allowed to dry for three days, after which the RRPC was applied to the entire boat-deck surface.

Two 1250 gal/hr Sellers injector units equipped with Spraying Systems Co. nozzles (1/2 P 15100) and one 6000 gal/hr Sellers injector unit equipped with a turret-mounted $1\frac{1}{2}$-in. playpipe nozzle were used to decontaminate the test areas. All personnel wore standard foul-weather clothing while using these hot-liquid jet units.

The following procedures for the removal of the RRPC were accomplished at SFNS after YAG-39 had returned. A two-man team using a 1250 gal/hr hot-liquid jet unit removed the RRPC from the area aft of the flight deck to the after end of Hatch 2, including both port and starboard gun tubs. The jet was operated at 160 to 170°F and approximately 185 psi.

A four-man team using a 6000 gal/hr hot-liquid jet unit removed the RRPC from the boat deck and from a strip along Hatch 5 from the port to the starboard rail. Operating conditions for this unit were approximately 180°F and 200 psi.

4.8.2 Results and Discussion

Observations were made on the application, wearability, and weatherability of the RRPC. Pertinent data were obtained on its removability characteristics after the ship returned to SFNS.

During application the solvent of the RRPC attacked the freshly applied deck gray paint on the boat deck and left it severely wrinkled. Well-aged, painted surfaces were not visibly affected.

The steel deck areas withstood considerable abrasive wear without noticeable failure.

Weathering of the vertical surfaces was generally satisfactory. The deck surfaces, however, weathered poorly. The film seemed to shrink or contract with age, and as a result it became detached from the surface, particularly around welded seams or rough spots on the surface. Once the film pulled away, it was easily broken and the entire lifted area could be peeled off. This phenomenon was also observed on the wood deck. Since the latter surface was very rough, the effect here appeared to be much more severe.

During stripping tests performed at the shipyard, an average stripping rate of 8 sq ft/min was obtained with the 1250 gal/hr hot-liquid jet unit. One vertical test area of 100 sq ft was stripped at a rate of 11 sq ft/min, and a 100-sq ft deck area was stripped at a rate of 17 sq ft/min.

An average stripping rate of 15 sq ft/min was obtained on steel deck surfaces with a 6000 gal/hr hot-liquid jet unit. The top of Hatch 5 (600 sq ft) was stripped at a rate of 24 sq ft/min. This unit removed the test coating from the wood boat deck at a rate of 13 sq ft/min.

In general, the film strength and abrasive resistance of the RRPC tested were good. Its removability characteristics were satisfactory except for the low removal rate obtained under the conditions of this test. Additional work will be required to improve the removal rate and to reduce the tendency of the RRPC to contract and pull away from the surface as it ages.

4.9 CONTAMINATION-DECONTAMINATION STUDIES

Radioactive simulants are used in laboratory experiments to simulate the deposition of fall-out and to measure the effect of a number of variables on its removal. Since the results from these experiments are applied to evaluate actual situations, it is important to determine how nearly a simulant demonstrates the same chemical and physical characteristics as the real contaminant. This may be accomplished by conducting experiments in the field with actual fall-out from nuclear devices. These data then guide the preparation of more realistic simulants.

The objectives of the contamination-decontamination studies were to:

1. Determine the contaminating properties of the radioactive sea water at Operation Wigwam for comparison with those of a laboratory-prepared simulant of neutron-irradiated uranium in total carrier solution.
2. Determine the effect of radiation level and the time of contact (aging) on the decontamination properties.
3. Investigate the fractionation or selective removal of elements by decontamination.
4. Compare methods of decontamination for their effectiveness on two surfaces when fresh water and chemical additives are used.

4.9.1 Experimental Procedures

Radioactive sea water collected as YAG-40 traversed the contaminated area was flown to CVL-49 by helicopter. It was used to contaminate sample surfaces. One-half of the samples were decontaminated upon arrival. Subsequently the second series was processed one week after contamination. Each series consisted of decontaminating 144 samples, as follows:

1. Two surfaces (weathered Navy gray paint and weathered galvanized iron).
2. Three levels of contamination (300, 3000, and 30,000 r/hr at 1 hr).
3. Four methods of decontamination (cold spray, hot spray, hot spray plus brushing, and hot solution with gentle stirring).
4. Three decontamination liquids (water, complexing agent EDTA, and anionic detergent Orvus).
5. Two duplicates.

This schedule permitted the samples to be contaminated at a realistic fall-out arrival time and to be decontaminated at realistic times after the event.

Gamma radiation was measured with the UDR-9 scintillation counter, and a single-channel gamma analyzer was used to study element fractionation. Autoradiographs were made on several samples before and after decontamination. Volhard chloride analyses were used to measure the volume of sea water initially deposited on the samples and the fraction of the deposit removed by decontamination.

(a) Laboratory Sample Surfaces. Ten 9-in.-square plates of $^1/_8$-in. aluminum were grooved on the underneath side to form a grid of 36 squares which could be broken into standard $1^1/_2$-in.-square samples; an equal number of galvanized-iron plates were similarly prepared. The aluminum plates were painted with full-system 5H haze gray. All plates were weathered in the Atlas Weatherometer for 90 hr, which simulates three months of natural weathering.

(b) Contamination. The radioactive sea water in the YAG-40 sample bottle IIB gave a contact reading of 100 mr/hr at 1630 on 14 May, which was less than one-third of the specified minimum requested in preoperational planning. Approximately 500 ml of this water was placed in each of the aspirator pots, and the contamination was started in both fog chambers* at 1700. Results from the first assay made by Project 2.3 were used as a guide to determine the minimum contamination time which would yield useful samples. Because a relatively large deposit would be needed for even the least contaminated sample to be counted at the laboratory, two plates of each surface were contaminated for 4, 8, and 12 hr. These samples were returned to the laboratory on the first flight which left CVL-49 at 0800 on 15 May.

Another group of plates were placed in the chambers at 0900, 15 May. They were left until the radioactive water in the aspirator pots was exhausted. These samples were returned to the laboratory on the second flight which left CVL-49 at 0900, 16 May.

(c) Decontamination. On 17 May the first series of samples was decontaminated by cold spray, hot spray, and hot spray plus brushing, using water, 1 per cent Orvus solution, and 1 per cent EDTA solution. The spray machine[3] was operated at 50 psig for 30 sec. The same solutions were used for decontamination by gentle stirring for 5 min. All samples were sufficiently active to give useful counts. On 23 May the second series of samples was processed, although only the highest level (the 12-hr samples) was countable (from the two contamination schedules).

(d) Supplemental Studies. Chloride titration: Five samples of each plate were immersed in 25 ml of distilled water and titrated by the Volhard method to determine the volume of sea water which had been deposited. Twenty-four decontaminated samples were similarly analyzed for chloride.

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*R. K. Fuller, W. B. Lane, and L. L. Wiltshire, Performance Characteristics of an Aerosol Contamination Chamber and Study of Decontamination Methods (in publication).

Autoradiographs: Autoradiographs of samples before and after decontamination were prepared.

4.9.2 Results and Discussion

The over-all experiment was completed as planned except for deviations caused by the low initial levels in the radioactive sea water. The third decontamination series was not accomplished because of decay.

The data for the decontamination of Navy gray paint samples were averaged, and the results are shown graphically in Fig. 4.17. The activity level before decontamination is plotted vs that after decontamination. The relative effectiveness of the four decontamination methods and of the three liquid decontaminants is clearly demonstrated. The decontamination effectiveness of Orvus is from eight to 15 times better than that of water alone. EDTA shows a slight improvement over Orvus with all methods except gentle stirring. The benefits of mechanical action in decontamination methods are evidenced by the upper position of the curve representing the gentle stirring method for all decontaminants, and the maximum effectiveness is always indicated by the hot hosing plus brushing (lowest) curve.

The data for the decontamination of galvanized-iron samples were averaged, and the results are shown in Fig. 4.18. Again the relative effectiveness of liquid decontaminants and decontamination methods is demonstrated. The advantage of the reagents EDTA and Orvus over water alone is less pronounced in the decontamination of galvanized iron than it was in the Navy gray paint case. Again the value of mechanical action in decontamination methods is evidenced by the spread between the curve for gentle stirring and the curve for hot hosing plus brushing.

A comparison of Figs. 4.17 and 4.18 reveals that, in general, galvanized iron is much more difficult to decontaminate than Navy gray paint.

The data for the second decontamination were not plotted because the nine-day decontamination experiments were limited by radioactive decay, and therefore the necessary differences in levels were not studied. Inspection of the data does not indicate any trends in decontamination values that could be attributed to the age of the contaminant.

Only two distinct levels of contaminant were obtained during the experiment; these differed by a factor of 3. In general, the linearity of the curves in Figs. 4.17 and 4.18 shows that there were no significant differences in the decontamination values that resulted from the levels of contaminant studied.

A comparison of the decay curves (Fig. 4.19) for gross gamma in the radioactive sea water and the gamma from the liquid aerosol shows that no measurable fractionation occurred during aspiration.

The data from the chloride titrations were converted first to mass of sea water deposited on the samples and then to radiation levels by a mass-radiation relation (25 mg/sq ft/r/hr at 1 hr). Contamination levels appeared to be between 80 and 250 r/hr at 1 hr. This range is approximately the same as the difference determined by gamma counting.

The amounts of the initial salt deposit that remained after decontamination were measured by chloride titration, which indicated that an average of only 1.5 per cent of the salt deposit remained as compared to an average of 41.0 per cent gamma remaining. Twelve Navy gray paint samples, with an average of 12 per cent gamma remaining showed that only 0.5 per cent of the salt deposit remained after decontamination. This demonstrates that the radionuclides react selectively with the surfaces instead of following the salt in their decontamination behavior.

4.9.3 Conclusions

The following conclusions can be drawn from this experiment:

1. Chemical additives, as represented by Orvus and EDTA, increase the decontamination effectiveness significantly when compared to water alone.

2. Compared to gentle stirring, the mechanical action from liquid impact and brushing increases the decontamination effectiveness significantly.

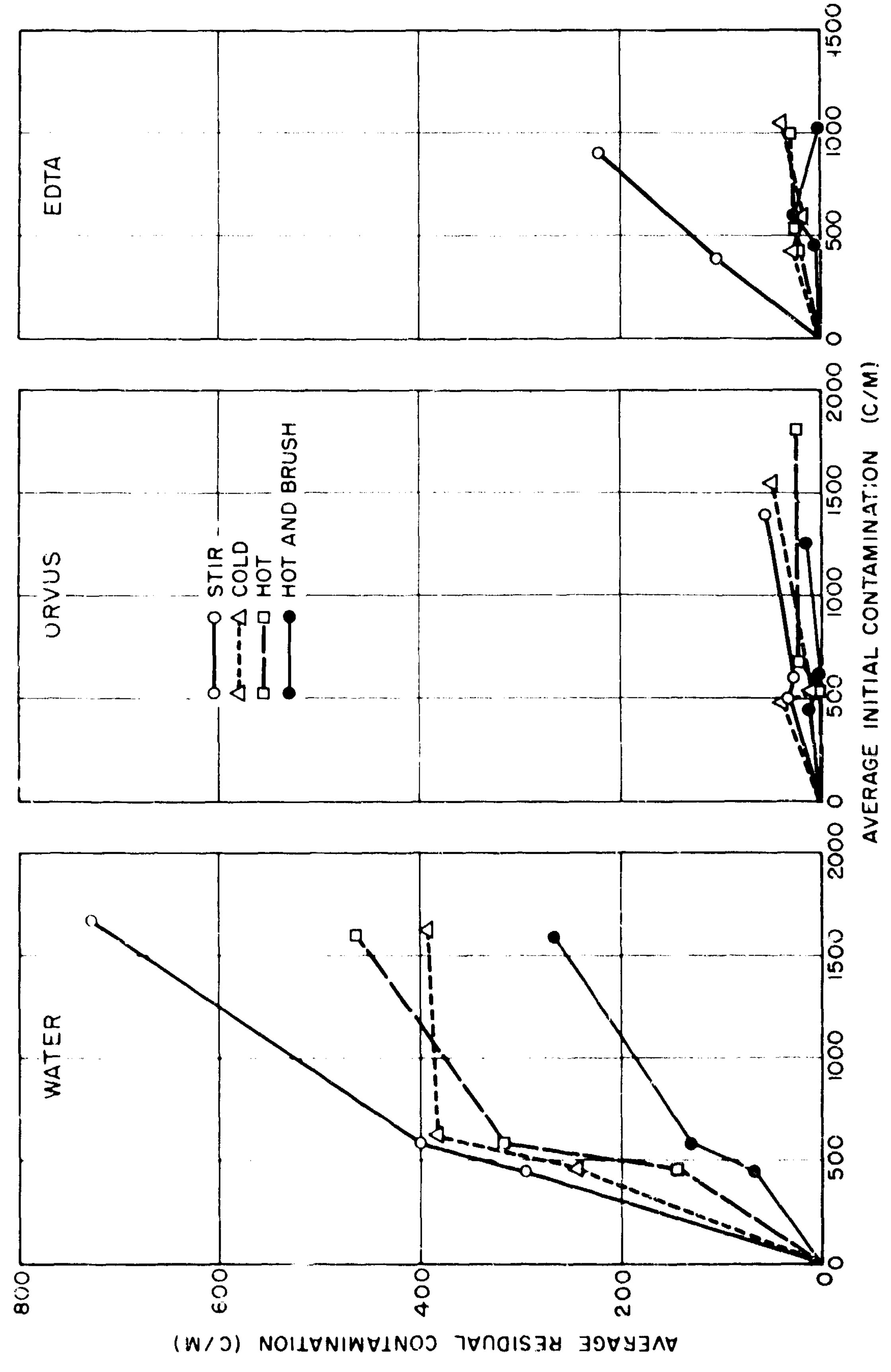

Fig. 4.17—Decontamination of Navy gray paint at H+3 days.

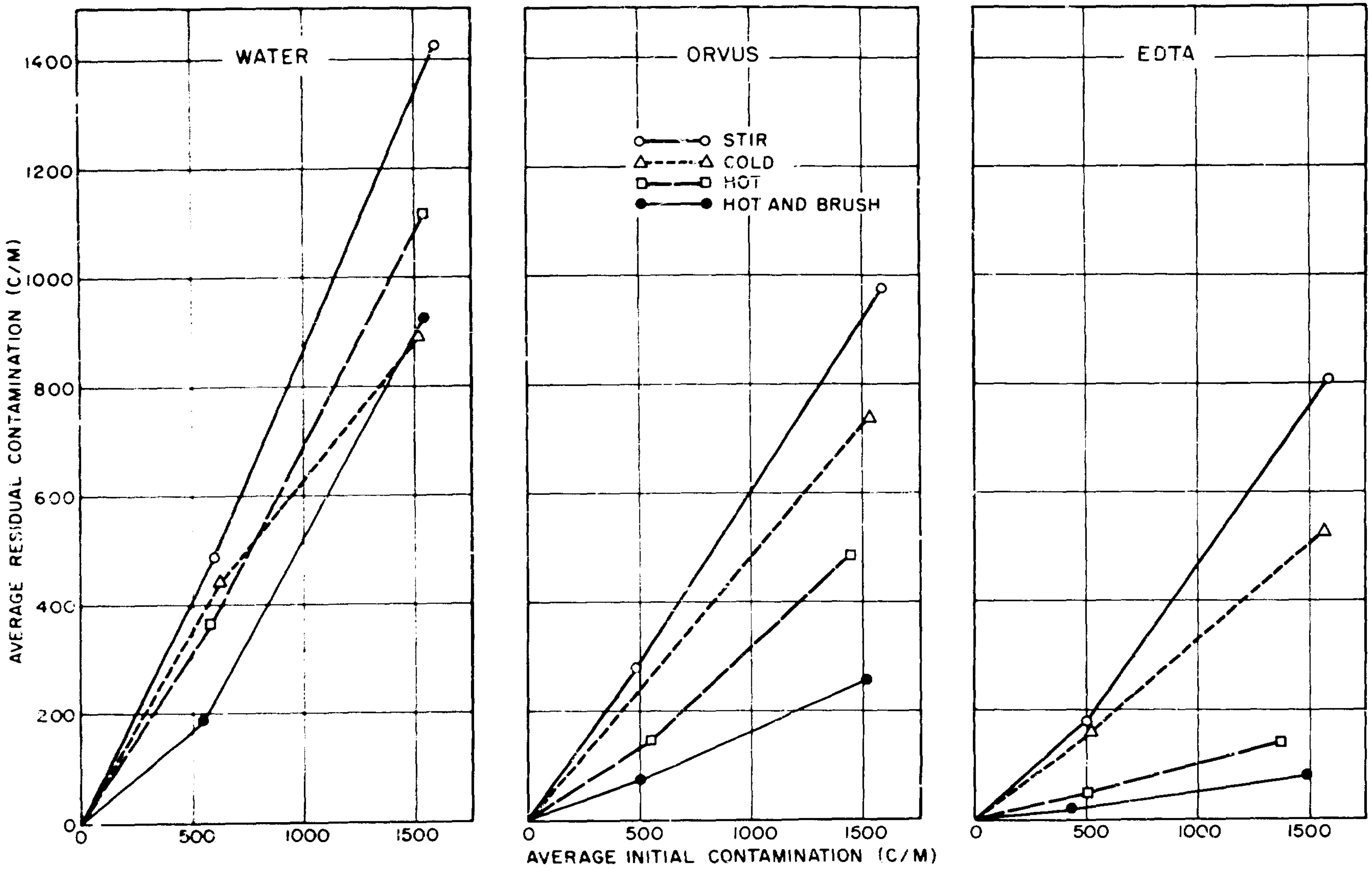

Fig. 4.18—Decontamination of galvanized-iron samples at H+3 days.

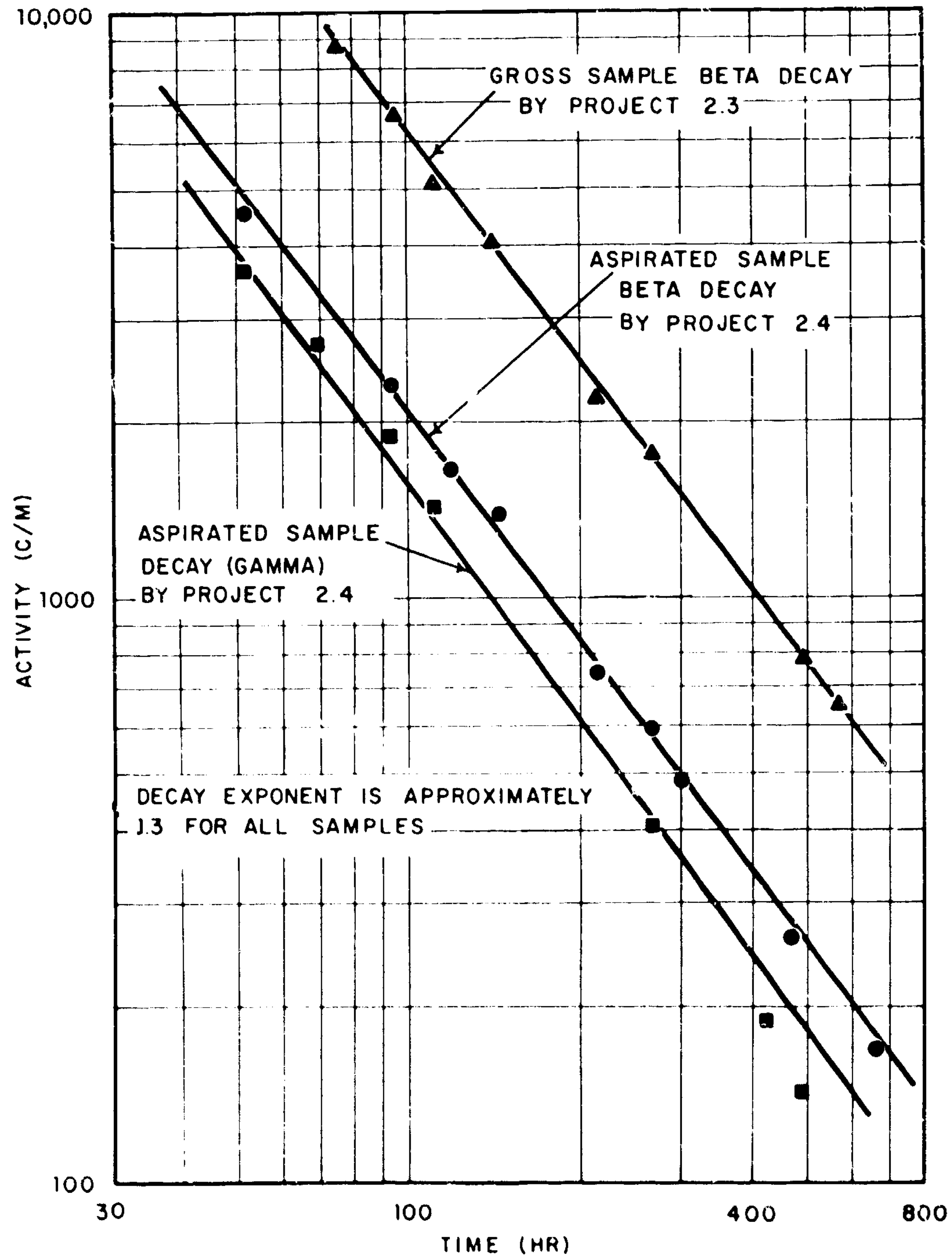

Fig. 4.19—Decay comparisons.

3. Galvanized iron is more difficult to decontaminate than Navy gray paint.

4. A comparison of decontamination measured by gamma counting with that measured by chloride analysis shows that the radionuclides do not necessarily follow the salt deposit in decontamination procedures but may adhere to the painted and galvanized surfaces, whereas the chloride is desorbed or dissolved.

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3. W. F. Joseph and R. M. Bond, A Gamma Discriminating Beta Survey Meter, U. S. Naval Radiological Defense Laboratory Report TR-22, 18 November 1954.
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5. San Francisco Naval Shipyard Industrial Laboratory Report 377-18046.

CHAPTER 5

WATER SAMPLING AND ANALYSIS

By R. R. Soule

Estimates of hazards to ships in various contaminating situations are based upon the interrelation of the amount of contamination in the water and the resultant radiation-field intensities. Sample collection and subsequent analysis are required for establishing the basis for such estimates.

5.1 OBJECTIVES

The general objectives of this portion of Project 2.4 were to determine (1) the extent and activity of the contaminated surface water as a function of time and (2) the characteristics of the contaminated water pertinent to an estimation of the relation of specific activity to dose rate. The specific objectives in the field were to (1) obtain samples of contaminated water, (2) determine the gamma activity of surface water as a function of time, and (3) determine the gamma decay of a quantity of the radioactive surface water. Also, surface and shallow-depth samples were collected for Projects 2.1 and 2.3.

5.2 INSTRUMENTATION

Instrumentation consisted of three components: a sampling system, an automatic analysis system, and a remote water-temperature recorder, all installed on YAG-40.

The sampling system was arranged so that sea water could be taken from either of two places by manipulation of appropriate valves. The water could be pumped from beneath the keel at a depth of about 30 ft, or surface water (18-in. depth) could be pumped from a "sled" that rode on the surface of the sea. After leaving the pump the water was piped to a manifold system. The manifold system was arranged so that 60 1-gal bottles could be filled with sea water in sets of three and so that four 13-gal bottles could be filled separately. The manifolds were controlled by solenoid valves which were operated remotely from the Secondary Control Room. Operation recorders located in the control room and in the manifold room recorded the time at which sets of bottles were filled and indicated which bottles were available for filling.

A portion of the water flowing through the manifold system was led to the shielded low-background room, where an automatic analysis system was installed in duplicate.

The automatic analysis system consisted of piping and valving, detector heads, log rate counting meters, recorders, and remote indication and control gear. The piping was arranged so that water could be led past two radiation detectors. The valving was arranged so that a portion of water could be trapped and held at one of the detectors for decay measurements.

Each detector consisted of two units, a low-range one and a high-range one. Scintillation counters were used as detectors with suitable shielding to approximate "relative-roentgen" response. Information from the detectors was fed to log rate meters and was recorded on four-cycle semilog charts. The information from the log rate meters was also repeated to the control room. Detectors were calibrated with a Co^{60} salt dissolved in water, thus establishing a ratio of counts per second to millicuries per milliliter. Energy characteristics of the detector system are indicated in Fig. 5.1, where the response of the system is compared to an ideal (air equivalent) ionization chamber. A station was set up in the Secondary Control Room to monitor and control the automatic analysis system.

A temperature-sensing element was placed in the sample-water inlet to determine whether the detonation caused any temperature change. The output of this unit was led to the Secondary Control Room, where it was recorded to an accuracy of ±0.15°C.

5.3 EXPERIMENTAL PROCEDURE

The ship made four passes through the contaminated area; on each of these passes, five sets of three 1-gal bottles were filled. In addition, four 13-gal bottles were filled during the first two passes. Thus a total of 112 gal of sea water was collected. On the basis of remote readings from the automatic analysis system, the operator in the Secondary Control Room trapped a sample of sea water for decay measurements.

In order to control radiation exposure, criteria were set up for determining (1) the amount of water to be valved into each bottle and (2) the number of bottles to be handled. Means were supplied for handling the bottles remotely, and shielded containers were provided for transporting them. After the first pass a number of bottles were transferred by helicopter to CVL-49, where early radiochemical analyses were performed by Project 2.3. Similarly, a number of bottles were transferred after the second pass, and a number were transferred by M-boat at the end of the day.

5.4 RESULTS AND DISCUSSION

Within the sensitivity of the recording system, there was no discernible temperature difference between contaminated and uncontaminated areas.

A total of 120 1-gal bottles were filled with samples of sea water.

Figure 5.2 shows the gamma decay of the radioactive material in the water as determined by the equipment in the low-background room. As indicated, the exponent n in the relation

$$\frac{A}{A_0} = \left(\frac{t}{t_0}\right)^{-n}$$

was found to be approximately 1.5 from 1 to 10 hr and 1.2 from 10 to 100 hr after detonation.

Figure 5.3 is a plot of the activity of the sea water vs time as indicated by the port analysis system. The data from the starboard system were in satisfactory agreement. A variable radiation background of the instrument was subtracted before plotting Fig. 5.3. The background was apparent at 1418, when the keel and other gamma-detector stations indicated that the ship was out of the contaminated area. Reduction of this background count was greater than would be expected to result from radiological decay alone; therefore it seems probable that the system was losing activity owing to washing. Sea water had been passing through the system long before contaminated water, and any tendency for it to adsorb ions should have been satisfied. Therefore the deposition of radioactive material should be primarily due to exchange processes. By similar reasoning one would expect that the loss of active material would also be due to exchange processes. If so, the amount of radioactive material lost from the system would be proportional to the amount present, or

$$\frac{dA}{dt} = kA$$

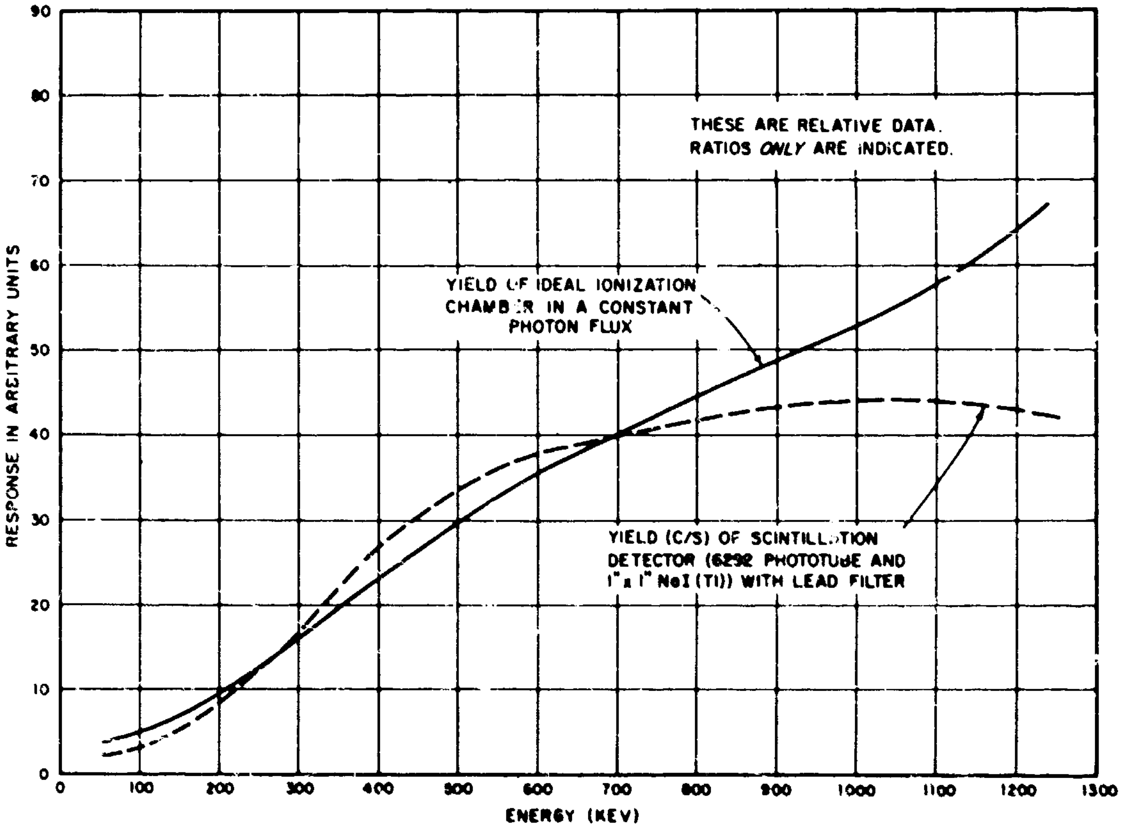

Fig. 5.1 — Energy characteristics of detector system.

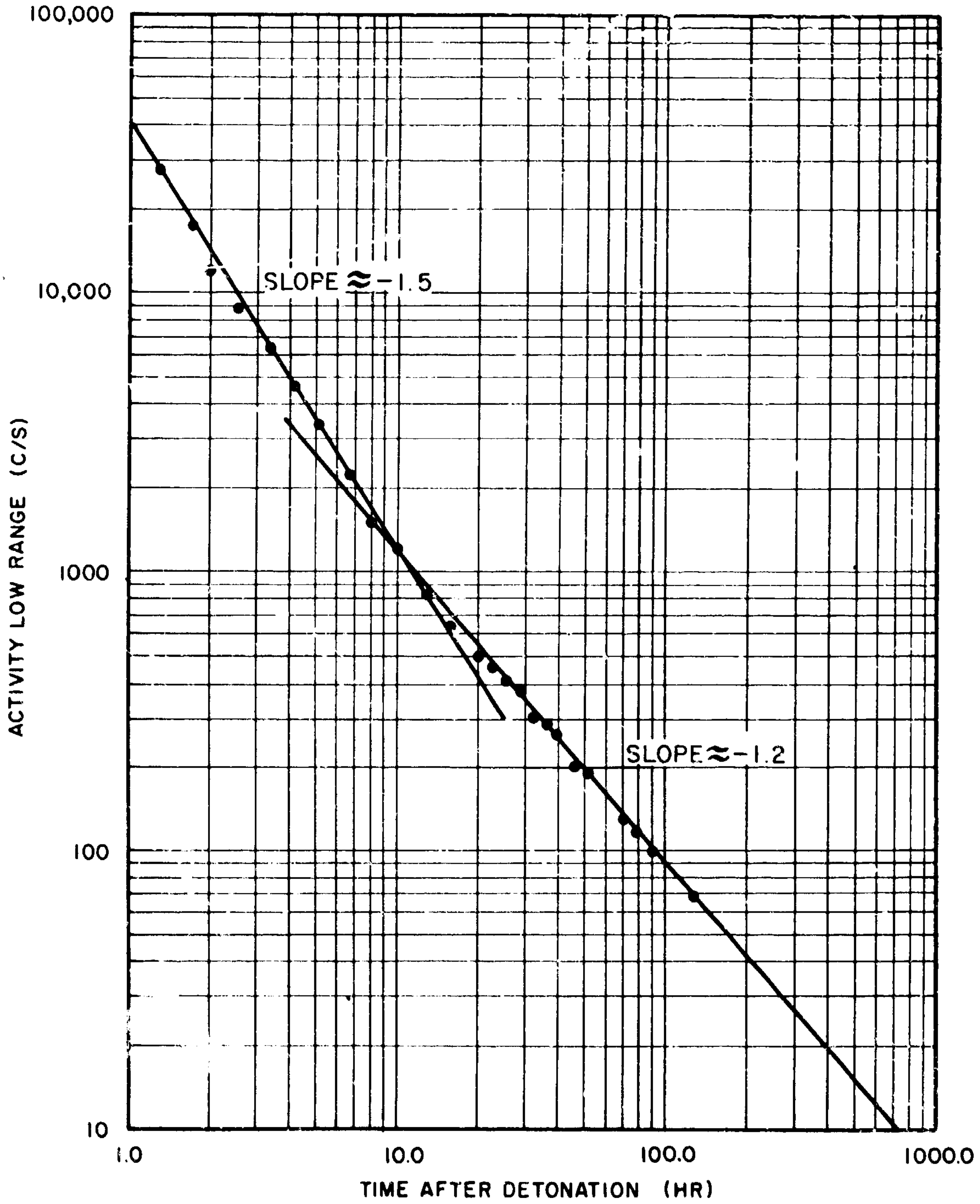

Fig. 5.2 — Gamma decay of sea water.

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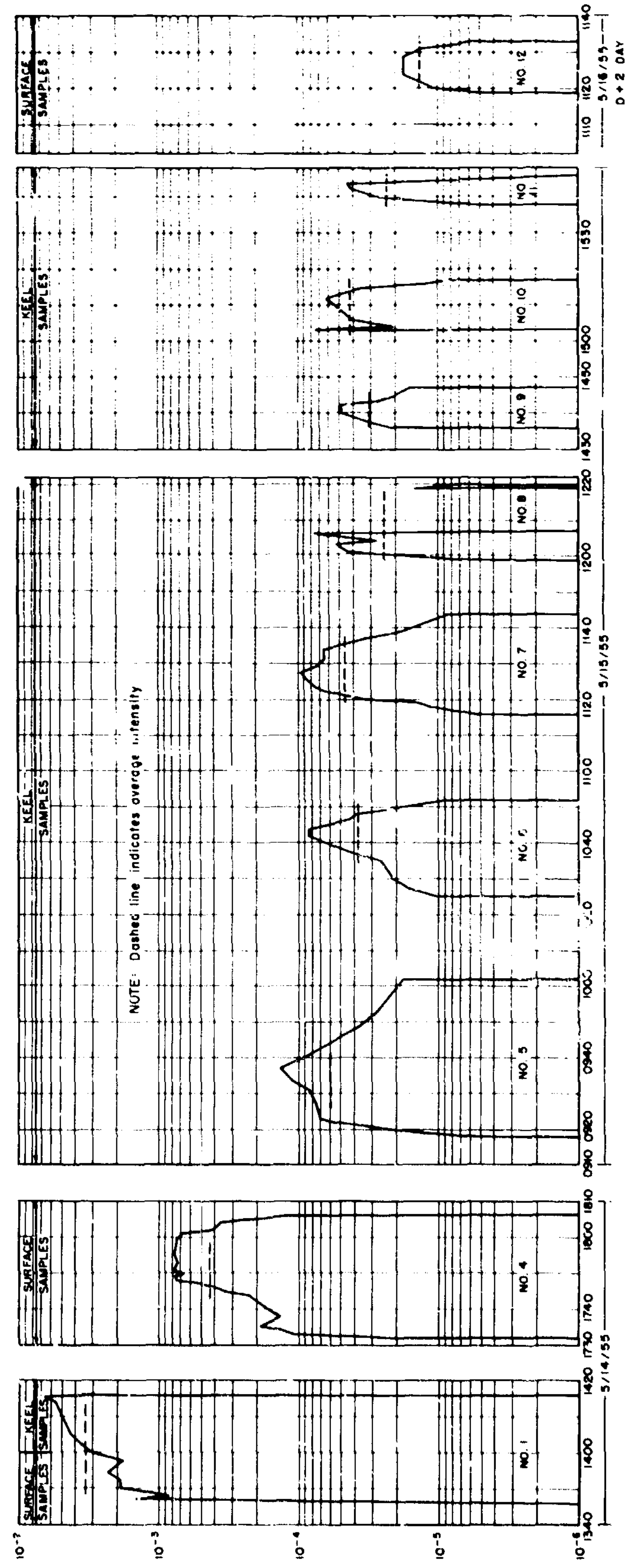

Fig. 5.3 — Sea-water activity vs time.

The solution of this equation yields

$$A = A_0 e^{-kt}$$

Loss due to radioactive decay alone is in accordance with

$$A = A_0 \left(\frac{t}{t_0}\right)^{-n}$$

Loss from a combination of radioactive decay and washing would then be represented by

$$\frac{A}{A_0} = \left(\frac{t}{t_0}\right)^{-n} e^{-k(t_0-t)}$$

Plotting the activity remaining in the system after 1418 (first day) and solving the above equation for n and k yield n = 1.55 and k = 0.08. The value of the radioactive-decay exponent is in good agreement with the value found for this time from the decay analysis detector (n = 1.50).

5.5 CONCLUSIONS

The specific activity of the contaminated area varied considerably from location to location. Consequently any generalization regarding the total contaminated volume derived from data from a limited number of samples is precarious.

The gamma decay exponent as derived herein (and based on a relative-roentgen response of the instruments) was about 1.5 from 1 to 10 hr and 1.2 thereafter.

CHAPTER 6

SUMMARY OF RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

6.1 RADIOLOGICAL ENVIRONMENT

The particular conditions under which the nuclear device was detonated at Operation Wigwam resulted in the following radiological environments: (1) a contaminated water area, (2) a downwind cloud of airborne radioactive debris, and (3) residual fall-out from the cloud. The latter sea areas were much lower in radioactivity (factor of 100 or more) than the main body of contaminated sea and probably have no tactical consequence.

The main contaminated sea area was about 5 sq miles in area at H+19 min, and the average "transit" intensities were about 25 to 30 r/hr at 3 ft above the surface. Peak activities were about three times the average.

The radioactive material was decaying during D-day at a rate represented by the exponent −1.5. The over-all decay-dilution exponent was −1.8. Although the area within the 50 mr/hr isorad increased temporarily, by about H+4 hr the area had decreased to about 3.5 sq miles and had an average transit intensity of 0.3 to 0.4 r/hr.

Assuming that the decay-dilution exponent −1.8 held at early times, the average transit intensity was about 3000 r/hr at H+2 min.

The downwind cloud had a gamma-radiation intensity of greater than 400 r/hr at about H+14 min. Assuming that the decay exponent −1.5 held at early times, the radiation intensity was about 10,000 r/hr at H+2 min.

6.2 RADIOLOGICAL HAZARD TO SHIPS

A limiting assumption of this report is that the radiological conditions encountered are typical of a nuclear device detonated under water in similar conditions of depth. Radiological hazard as defined for this experiment is primarily related to external gamma-radiation dosage.

6.2.1 Actual Situation on YAG-39

YAG-39, which intercepted the airborne activity at about H+14 min, encountered, for a short period, topside radiation fields in excess of 400 r/hr. The washdown system was used to prevent and reduce the amount of residual contamination. The over-all dose accumulated topside on D-day was about 30 r. Interior spaces protected by one layer of "skin" received about 6 to 12 r. Other spaces were significantly lower. Radiation on deck averaged about 9 mr/hr at H+1 hr and about 0.1 mr/hr at H+19 hr.

The D+1 day traverse of the contaminated area with the washdown on increased the radiation level on deck to about 0.5 mr/hr but did not materially increase the dosage.

Upon return to ZI, YAG-39 was granted an operational clearance after only a minor, spot decontamination.

6.2.2 Actual Situation on YAG-40

YAG-40 intercepted the contaminated surface area at H+46 min. During the first 24 hr, the ship was in the contaminated area some $2\frac{1}{2}$ hr. The resultant average weather-deck dosage was 1.6 r. Interior spaces received less, the maximum being 0.1 of the deck dosage.

Neither the hull nor the piping-system contamination was significant.

Upon return to ZI and after spot decontamination, YAG-40 was granted a limited operational clearance.

6.3 COUNTERMEASURE STUDIES

6.3.1 Washdown

Traversing the contaminated area with the washdown system on did not increase the radiation levels on deck a measurable amount during the test. Residual radiation levels resulting from the washdown water being contaminated were 4 per cent of the peak intensities encountered on deck.

Subsequent to envelopment by the downwind cloud, the washdown-system effectiveness based upon the residual dose rate was 95 to 98 per cent. However, about 97 per cent of the radiation dosage received on the ship was "transit dose" from the cloud itself rather than from the residual contamination. Thus the over-all effectiveness of the washdown in reducing radiation dosage as measured in this particular situation was only about 14 per cent.

6.3.2 Hull Paint

In traversing the contaminated water area, residual radiation levels in the holds resulting from contaminated hull paints were $2\frac{1}{2}$ to $5\frac{1}{2}$ per cent of the average levels encountered during the traverse of the area. Steaming through clean water apparently decontaminated the surfaces to some extent. The contaminability of the different paints varied, but the differences were insignificant compared to the dose received during the transit.

6.3.3 Contamination-Decontamination

Chemical additives, as represented by Orvus and EDTA, increase the decontamination effectiveness significantly when compared to water alone. Compared to gentle stirring, the mechanical action from liquid impact and brushing increases the decontamination effectiveness significantly. Galvanized iron is more difficult to decontaminate than Navy gray paint. A comparison of decontamination measured by gamma counting with that measured by chloride analysis shows that the radionuclides do not necessarily follow the salt deposit in decontamination procedures but may adhere to the painted and galvanized surfaces, whereas the chloride is desorbed or dissolved.

6.4 EXTRAPOLATED SITUATIONS

YAG-39 and YAG-40 for various reasons entered the radiological environments at relatively late times. Ships involved directly or indirectly in the actual warfare might become involved at very early times when the radiation intensities are much higher.

6.4.1 Situation Resulting from Airborne Activity

To extrapolate the conditions encountered on YAG-39 to earlier times, it was assumed that the decay of the airborne activity followed a function with an exponent of −1.5. It was also assumed that the dose accumulated on the ship during the contaminating event was equivalent to that received while encountering a uniform (except for decay) radiation field during an equivalent time period. The 30 r received on the deck of YAG-39 was received during a 7-min period, starting at about H+14 min. An equivalent dose would be accumulated by entering a uniform 300 r/hr radiation field at H+15 min and leaving at H+22 min. This same field would be about 3400 r/hr at H+3 min (assuming a decay exponent of −1.5). The dose accumulated from H+3 to H+10 min would be about 150 r.

6.4.2 Situation Resulting from Surface Contamination

A ship traveling at 30 knots on a course toward SZ and 2 miles from it would intercept the contaminated surface area at about 2 min after detonation if no evasive action were taken. The ship would be in the area for about 4 min.

Assuming that the curve in Fig. 3.9 holds for earlier times, the average radiation intensity 3 ft above the contaminated area at time of entry would be about 3000 r/hr and at time of exit would be about 350 r/hr. The accumulated dose (3 ft above the surface) during traverse would be about 70 r. Assuming that this ship has the same dimensions and shielding characteristics as YAG-40, a comparison of the data indicates the deck dose should be about 0.4 times this value. Thus the deck dose would be about 30 r. Interior doses would be lower.

If the ship should become immobilized in the contaminated area for 1 hr (starting at H+2 min), it would receive about 45 r deck dosage (or 50 r if immobilized to infinity). If trapped in a location of peak rather than average intensity (Table 3.2 indicates peak to average intensity ratios of about 3), the dosage might be 150 r.

6.5 CONCLUSIONS—SHIP HAZARD, TACTICAL

The radiological situations actually encountered by YAG-39 and YAG-40 cannot be considered tactically serious unless similar situations were to be encountered frequently.

The extrapolated situations at early times may be of tactical significance. However, the radiological situation changes extremely rapidly, and the hazard decreases accordingly.

Therefore it appears that ships can operate in and around underwater nuclear detonations if interception of the airborne activity and the contaminated surface is delayed to about H+10 min and if repeated exposures to new detonations are not anticipated. This conclusion is of course preliminary and subject to revision after more adequate operational analysis.

As previously indicated, the consequences of the use of the washdown system during traverses of the contaminated area were not well enough documented to draw firm conclusions. However, if a basic philosophy of avoiding any unnecessary radiation exposure is followed, it appears that the washdown system should not be used during traverses of the contaminated water area but should be used when airborne activity occurs.

It should be noted that the apparent insignificant effect of the washdown system in supplying protection from the cloud at Operation Wigwam in no manner negates the requirement for the system in other radiological situations.

Extrapolation of the situations to other weapons or detonation conditions can be only of a general nature. The depth of detonation at Operation Wigwam undoubtedly resulted in less surface and airborne contamination than would be generated by the detonation of a similar weapon at shallower depths. Increase of the energy release of the weapon could also increase the amount of surface contamination. Thus it follows that, since the radiological conditions at Operation Wigwam could have been serious, the radiological situation could be very serious under different conditions of detonation.

6.6 RECOMMENDATIONS

At Operation Wigwam the nuclear device was detonated under conditions that minimized the surface effects. The amount of surface and airborne contamination was also probably minimized. Other detonating conditions will probably result in radiological situations of tactical significance to the Navy. It is therefore recommended that, at every opportunity, studies similar to those in this project be conducted. Emphasis should be placed upon determining the extent of hazards encountered on tactical ships in situations of operational importance. The radiological environment encountered in the "throw-out" area should be determined. Portions of this study not completed, such as the proof test of decontamination procedures and effectiveness of strippable coatings, should be investigated. The significance of the ingress of contaminant through ventilation and combustion air systems should be studied.

In addition, the Navy should develop the techniques and instrumentation necessary for aerial "mapping" of such contaminated areas.